Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu

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Rozprawa doktorska

Zmiany w rozwoju somatycznym i motorycznym dzieci z regionu Wielkopolski w kolejnych dekadach od 1986 do 2016 w świetle wybranych zmian środowiskowych

W formie cyklu artykułów opublikowanych w czasopismach naukowych

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Doctoral dissertation

Changes in the somatic and motor development of children from the Wielkopolska region in the decades from 1986 to 2016 in the context of selected environmental changes

Akademia Wychowania Fizycznego
im. Eugeniusza Piaseckiego w Poznaniu

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Spis treści

I. Autoreferat

Podstawą rozprawy doktorskiej jest cykl publikacji pod wspólnym tytułem: ***Zmiany w rozwoju somatycznym i motorycznym dzieci z regionu Wielkopolski w kolejnych dekadach od 1986 do 2016 w świetle wybranych zmian środowiskowych***.

W skład cyklu wchodzi pięć artykułów przygotowanych na podstawie przeprowadzonych czterech serii obserwacji w: 1986, 1996, 2006 i 2016 roku. Realizację pierwszych trzech serii sfinansowano ze środków Komitetu Badań Naukowych Zakładu Teorii Sportu. Ostatnia z nich prowadzona w 2016 roku sfinansowana została w ramach realizacji projektu Rozwój Młodych Pracowników Nauki w Akademii Wychowania Fizycznego w Poznaniu.

Cykl składa się z następujących artykułów:

1. ***Secular change in height and weight of rural school children and youth in west-central Poland: 1986 to 2016.*** American Journal of Human Biology: The Official Journal of the Human Biology Council, 33(2), e23461. https://doi.org /10.1002/ajhb.23461 Impact Factor: 1.937, punktacja MEiN: 70.000
2. ***Weight status of rural school youth in Poland: Secular change 1986-2016.*** Anthropologischer Anzeiger; Bericht Uber Die Biologisch-Anthropologische Literatur, 79(1), 43–56. https://doi.org/10.1127/anthranz/2021/1500 Impact Factor: 0.877, punktacja MEiN: 70.000
3. ***Age at menarche among rural school youth in west-central Poland: variation with weight status and population growth*****.** Anthropological Review, 2021 84(1), 51-58. https://doi.org/10.2478/anre-2021-0006 punktacja MEiN: 70.000
4. ***Physical Fitness of Rural Polish School Youth: Trends between 1986 and 2016*** Journal of Physical Activity and Health, 2021 28;18(7):789-800. https://doi.org/ 10.1123/jpah.2020-0712. Impact Factor: 2.592, punktacja MEiN: 70.000
5. ***Relationship between BMI and physical fitness of Polish School Youth: Trends between 1986 and 2016*** Acta Kinesiologica 2021, 15 (2):134-143 https://doi.org/10.51371/issn.1840-2976.2021.15.2.18 punktacja MEiN: 140.000

Dane bibliometryczne cyklu to: wskaźnik IF 5,406 oraz 420 punktów MEiN

Struktura autoreferatu obejmuje następujące części:

1. **Wstęp**, w którym przedstawiono przegląd piśmiennictwa związanego z aktualnym stanem wiedzy w omawianym obszarze. W szczególności uwzględniono kierunki zmian cech somatycznych i zdolności motorycznych oraz wskazano ich ewentualne uwarunkowania. Rozdział ten kończy się podsumowaniem, wyjaśniającym potrzebę podjęcia tematu.

2. **Cel badań** - rozdział, w którym przedstawiono cel pracy doktorskiej oraz pytania badawcze.

3. **Materiał i metody badań**, w którym scharakteryzowano podmiot badań (materiał) i metody badawcze zastosowane w pracy.

4. **Wyniki**, rozdział ten podzielono na pięć podrozdziałów zgodnie z problematyką podjętą w kolejnych opublikowanych artykułach, wskazując na najistotniejsze, według autorki, spostrzeżenia nawiązujące do poszczególnych celów i pytań badawczych. Każdy podrozdział kończy się krótkim podsumowaniem.

5. **Dyskusja**, jest to część wspólna dla wszystkich artykułów z cyklu, w której przedstawiono ewentualne przyczyny mogące mieć wpływ na uzyskane wyniki.

6. **Ograniczenia pracy,** wskazano tu ograniczenia pracy, o które mogą zostać wzbogacone kolejne, prowadzone w przyszłości obserwacje.

7. **Wnioski,** w którym zawarto odpowiedzi na postawiony cel i pytania badawcze w konfrontacji z przeprowadzonymi analizami wyników.

1. Wstęp

Środowisko naturalne ulega nieustannym przeobrażeniom, które wpływają na organizmy żywe. W celu utrzymania wewnętrznej równowagi, niezbędne jest występowanie procesów adaptacyjnych, których efektem są między innymi zmiany w budowie somatycznej i poziomie zdolności motorycznych.

Zmiany genotypu organizmów żywych w tym człowieka mogą zachodzić w zakresie pewnej normy zwanej normą reakcji, której poziom rozwinięcia zależeć będzie, oprócz uwarunkowań genetycznych, od wpływu poszczególnych czynników środowiskowych. Wyróżnia się trzy główne grupy czynników warunkujących dynamikę rozwoju biologicznego człowieka w ontogenezie. Należą do nich czynniki: endogenne genetyczne – determinanty rozwoju, endogenne paragenetyczne – stymulatory rozwoju oraz egzogenne – modyfikatory rozwoju. W ostatniej grupie wyróżnia się dwie podgrupy. Pierwszą z nich stanowią biogeograficzne modyfikatory naturalne, do których zalicza się faunę i florę, skład wody, powietrza, gleby, zasoby mineralne, ukształtowanie terenu i klimat. Drugą natomiast stanowią modyfikatory społeczno-kulturowe takie jak pochodzenie społeczne, charakter i wielkość środowiska, poziom wykształcenia, wysokość zarobków, tradycje i zwyczaje społeczne. Czwartym wyróżnianym czynnikiem, leżącym na pograniczu uwarunkowań genetycznych i środowiskowych, jest styl życia (Cieślik i wsp., 1985)

Przykładem wyżej opisanych czynników mogą być również zmiany polityczno-gospodarcze zachodzące w poszczególnych krajach, położenie geograficzne, zanieczyszczenie powietrza, czy poziom urbanizacji regionu. Mogą one wpływać na występowanie powolnych, długofalowych, kierunkowych efektów w postaci tzw. zmian międzypokoleniowych (z języka angielskiego: *secular trends* - trendy sekularne*)* w obrębie parametrów charakteryzujących poziom biologicznego i morfologicznego rozwoju populacji.

Obserwacja trendów sekularnych opisujących zmiany wielkości ciała dzieci, młodzieży oraz dorosłych ma bardzo bogatą, tradycję zarówno globalnie, opisując zmiany pomiędzy kontynentami czy państwami jak i lokalnie, ukazując zmiany w danym kraju lub jego regionie (Malina, 1979, 2004; Roche, 1979; Tanner, 1962, 1981, 1992). Również w Polsce od ponad 100 lat dokonuje się podobnych obserwacji (Bielicki, 1986; Bielicki i Szklarska, 1999; Jankowiak, 1962; Jasicki, 1938; Łopuszańska-Dawid i wsp., 2020; Trześniowski, 1990). Publikowane dane konsekwentnie wskazują na miejsko-wiejski gradient wielkości osiąganych w czasie (Hulanicka i wsp., 1990; Łaska Mierzejewska i wsp., 2016; Nowak, 2012; Przewęda

i Dobosz, 2003), należy jednak zauważyć, że różnice między dziećmi i młodzieżą miejską i wiejską zmniejszyły się w ciągu ostatnich 40 lat. Jako przykładowe czynniki wpływające na taki stan rzeczy wymienia się między innymi zmiany w strukturze polskiej wsi, na którą wpłynęła likwidacja Państwowych Gospodarstw Rolnych (PGR) po 1992 roku, możliwość korzystania z programów Unii Europejskiej, takich jak Program Rozwoju Obszarów Wiejskich działający w Polsce od 2007 roku oraz rozwój cyfryzacji wpływający na proces upowszechniania wiedzy (Gomuła i wsp., 2015; Łaska-Mierzejewska i wsp., 2016; Łaska-Mierzejewska i Olszewska, 2003, 2009; Janowski, 2017; Saczuk, 2018).

Obserwowane w ostatnim czasie przyrosty wysokości i masy ciała dzieci i młodzieży wiejskiej w Polsce były zgodne z tymi występującymi wśród populacji ogólnej oraz pochodzącej z dużych miast (Bielicki i Szklarska., 1999; Przewęda i Dobosz., 2003; Gomuła i wsp., 2015). Przykładowo, w badaniach prowadzonych w odstępach dekadowych od 1986 do 2016 odnotowano w pierwszych dwóch terminach istotny przyrost wysokości i masy ciała dzieci i młodzieży szkolnej zamieszkującej miasta i wsie w kilku województwach we wschodniej Polsce. Kolejne obserwacje wykazały utrzymanie się tendencji wzrostowej, jednakże zmiany były niewielkie i nie istotne statystycznie (Saczuk, 2018). Wśród dzieci w wieku szkolnym od 7 do 15 lat pochodzących z siedmiu miejscowości wiejskich w okręgu górnictwa miedziowego na Dolnym Śląsku, wysokość i masa ciała zwiększyły się znacząco w latach 2000-2001 i 2010-2011, chociaż masa ciała wzrosła proporcjonalnie w większym stopniu niż wysokość ciała (Ignasiak i wsp., 2016).

Wielkości zmian wysokości i masy ciała wpływają na zmiany wskaźnika wagowo-wzrostowego - Body Mass Index (BMI, kg/m^2). W Polsce, podobnie jak i w większości krajów wysoko rozwiniętych, od lat obserwuje się niekorzystną tendencję związaną ze wzrostem liczby dzieci z nadwagą i otyłością, której następstwem są poważne, negatywne skutki zdrowotne. Dodatkowo podjęte interwencje nie przynoszą zakładanego rezultatu, a tempo wzrastania nadwagi i otyłości wpłynęło na określenie jej mianem epidemii (Levin, 2000; WHO, 2000).

Zmiany w stylu życia, zwyczajach żywieniowych i ograniczanie ilości czasu poświęcanego na codzienną aktywność fizyczną oraz zmiana stylu życia na sedentarny są często wskazywane, jako podstawowe czynniki związane z rosnącą częstością występowania nadwagi i otyłości wśród dzieci i młodzieży (Lobstein i wsp., 2004; Hu, 2011). Pomimo, iż obecne dyskusje przede wszystkim koncentrują się na nadwadze i otyłości, istnieje również

problem związany ze zbyt niską masą ciała w stosunku do wysokości (niski wskaźnik BMI), określaną, jako niedowaga lub chudość. Obserwuje się wysokiego poziomu niedowagi w niektórych obszarach świata lub w niektórych grupach społecznych (de Onis i wsp., 2007; de Onis i Lobstein, 2010).

Trendy sekularne zmienności wskaźnika BMI i/lub rozpowszechnienia nadwagi i otyłości wśród dzieci oraz młodzieży w Polsce podobnie jak obserwacje dotyczące zmian wysokości i masy ciała były przedmiotem badań w próbach ogólnopolskich (Gomuła i wsp., 2015), ale także regionalnych (Chrzanowska i wsp., 2007; Mazur i wsp., 2014; Saczuk i Wasiluk, 2014; Perenc i wsp., 2016). Obejmowały one przeważnie lata 1966-2014, choć odstępy czasowe między poszczególnymi badaniami były różne. Dla kontrastu, tylko jedno z nich odnosiło się do problemu nadmiernej chudości i dotyczyło zmian pomiędzy 1986 a 2006 rokiem (Saczuk i Wasiluk, 2014).

Zmiany w zakresie wysokości, masy ciała oraz wskaźnika BMI mogą wpływać na wiek występowania pierwszej miesiączki (menarche), który jest powszechnie uznanym wskaźnikiem dojrzałości biologicznej kobiet. Na świecie obserwowany trend obniżania się wieku pierwszej miesiączki był ogólnie związany z poprawą warunków życia, stanu zdrowia, warunków żywieniowych oraz z rozwojem społeczno-ekonomicznym (Nieczuja-Dwojacka i wsp., 2018). Sugeruje się również, że średni wiek pierwszej miesiączki w niektórych populacjach może zbliżać się do "granicy genetycznej", biorąc pod uwagę zmniejszone związki z czynnikami społeczno-ekonomicznymi i środowiskowymi (Golding i wsp., 2001).

Odpowiednie dane dla Polski, pochodzące z końca XIX wieku, wskazują na medianę wieku menarche wynoszącą 15,2 lat (Kowalska, 1966). Nowsze analizy wyników badań krajowych odnotowały międzypokoleniowe spadki wieku występowania pierwszej miesiączki do 12,9 lat oraz utrzymywanie się kontrastów miejsko-wiejskich w latach 1966-2012 (Gomula i Kozieł, 2018). Podsumowując odnotowano, że mediana wieku menarche dziewcząt zamieszkałych na wsi występowała średnio później, niż u dziewcząt miejskich. Z kolei córki wiejskich rodzin nierolniczych osiągały menarche wcześniej niż pochodzące z rodzin rolniczych (Łaska-Mierzejewska i wsp., 2016).

Przyjmuje się, że określony poziom cech somatycznych stanowi predyspozycję do uzyskiwania wysokiego poziomu poszczególnych zdolności motorycznych. Analizowanie zmian poziomu zdolności motorycznych, będącej efektem predyspozycji i podejmowanej aktywności fizycznej, w odniesieniu do zdrowego stylu życia, młodzieży szkolnej ma długą

tradycję (Malina, 1978; Malina, 2004; Malina i wsp., 2004), a zainteresowanie tym tematem nasiliło się ostatnio w dobie konstruowania przeglądów systematycznych (Dooley i wsp., 2020; Tomkinson i Olds, 2007). Takie spojrzenie na omawiany problem jest kontynuowane w wielu krajach, choć przedziały czasowe i brane pod uwagę elementy sprawności fizycznej różnią się (Tomkinson i Olds, 2007; Fraser i wsp., 2019).

Mając na względzie obawy dotyczące obniżania się poziomu sprawności fizycznej młodzieży oraz jej potencjalne związki ze stanem zdrowia w wieku dorosłym (Lamb i wsp., 1988), najwięcej miejsca w badaniach poświęca się wydolności układu krążenia. Ponadto, aktywny fizycznie styl życia w okresie młodzieńczym, który zakłada wystarczający poziom umiarkowanej i intensywnej aktywności fizycznej, jest powszechnie akceptowany jako strategia promocji zdrowia i zapobiegania chorobom (Strong i wsp., 2005). Sprawność i aktywność fizyczna młodzieży potencjalnie pozytywnie wpływają również na poziom jakości życia, który może utrzymywać się w życiu dorosłym, o ile będzie systematycznie podtrzymywany i rozwijany.

Badania sprawności fizycznej polskiej młodzieży w wieku 7-19 lat datuje się od 1932 roku (Mydlarski, 1934), natomiast sprawność fizyczną młodzieży w Krakowie po raz pierwszy zbadano w 1938 roku (Bocheńska, 1972). Powyższe obserwacje przeprowadzono w okresie od 1918 roku, kiedy Polska odzyskała niepodległość, do 1939 roku, kiedy rozpoczęła się II wojna światowa. Kolejne ogólnopolskie badania sprawności fizycznej dzieci i młodzieży w latach 1951, 1966 i 1979 (Trześniowski, 1961, 1990), obejmowały okres powojennej kontroli komunistycznej, a porównania przedwojennych i powojennych poziomów sprawności fizycznej, w kilku testach, wykazały nieistotne zmiany pomiędzy 1932 a 1951 rokiem w ogólnopolskich testach sprawności (Trześniowski, 1961) i niejednolite zmiany między 1938 a 1962 rokiem u chłopców z Krakowa (Bocheńska, 1972).

W początkowych badaniach prowadzonych w Polsce koncentrowano się głównie na pomiarach szybkości, siły i mocy, w nowszych korzystano z międzynarodowych baterii testów sprawności fizycznej, stosując na przykład: Międzynarodowy Test Sprawności Fizycznej (MTSF) (Larson, 1974), EUROFIT (Council of Europe, 1993), a także test Coopera (Cooper, 1968), jako miernik wytrzymałości sercowo-naczyniowej. W ten sposób sprawność fizyczna polskiej młodzieży została umiejscowiona w kontekście społeczności europejskiej i międzynarodowej. Wyniki dzieci i młodzieży polskiej w testach sprawności fizycznej (szybkości, mocy i siły) były zróżnicowane w badaniach przed i po II wojnie światowej.

Po uwzględnieniu różnic w zastosowanych testach, zaobserwowano, że poziom sprawności fizycznej polskiej młodzieży generalnie poprawiał się w okresie do 1981 roku. Natomiast w ostatnich dekadach opisywane wyniki sprawności charakteryzowały się różnymi kierunkami i wielkościami zmian. Podobnie jak w przypadku obserwacji cech somatycznych dostrzegano kontrast pomiędzy „miastem a wsią" w kilku próbach sprawności fizycznej w ogólnopolskim badaniu z 1999 roku (Przewęda i Dobosz, 2003).

Na tle przedstawionych faktów wynikających z przeglądu piśmiennictwa stwierdzono, że pojawia się potrzeba podjęcia badań ukierunkowanych na znalezienie związków pomiędzy zróżnicowanym tempem rozwoju somatycznego i motorycznego, a jego wybranymi uwarunkowaniami środowiskowymi.

2. Cel badań

Celem badań było określenie wielkości i kierunków zmian w rozwoju wybranych cech somatycznych i zdolności motorycznych dzieci i młodzieży ze środowiska wiejskiego regionu Wielkopolski oraz poszukiwanie ich prawdopodobnych przyczyn środowiskowych w aspekcie społeczno-gospodarczym.

Pytania badawcze:

1. Czy występują zmiany poziomu wybranych cech somatycznych dzieci i młodzieży z regionu Wielkopolski, a jeżeli tak, to, jaki jest ich kierunek i wielkość? [publikacja 1 i 2]

2. Czy występuje relacja pomiędzy wiekiem występowania pierwszej miesiączki a grupami stanu odżywienia wśród dziewcząt z obserwowanego regionu Wielkopolski, a jeżeli tak to, jaki jest jej charakter? [publikacja 3]

3. Czy występują zmiany poziomu zdolności motorycznych dzieci i młodzieży z regionu Wielkopolski, a jeżeli tak, to jaki jest ich kierunek i wielkość? [publikacja 4]

4. Czy występuje relacja pomiędzy BMI a zdolnościami motorycznymi w grupie obserwowanych dzieci i młodzieży z regionu Wielkopolski, a jeżeli tak to, jaki jest jej charakter? [publikacja 5]

5. Czy występują okresy wzmożonego rozwoju cech somatycznych i zdolności motorycznych w kolejnych dekadach obserwacji wśród obserwowanych dzieci i młodzieży oraz czy dotyczą tych samych przedziałów wieku w kontekście zmian społeczno-gospodarczych? [publikacja 1, 2 i 4]

3. Materiał i metody badań

Badania realizowane były w czterech seriach w odstępach dekadowych. Pierwsza odbyła się w 1986 roku (Strzelczyk, 1995), druga w 1996 (Janowski, 2001, Karpowicz, 2001), trzecia w 2006 (Janowski, 2017), a czwarta w 2016 (Bartkowiak i wsp., 2021a; 2021b; 2021c; 2021d; 2022).

Badania przeprowadzono w 10 miejscowościach wiejskich regionu Wielkopolski: Kołaczkowo, Kłecko, Nekla, Pamiątkowo, Biedrusko, Strykowo, Granowo, Wojnowice, Kwilcz i Obrzycko. Wyboru poszczególnych szkół dokonano podczas pierwszej serii badań w 1986 roku, a podstawowym kryterium były możliwości techniczno-organizacyjne pozwalające na wykonanie badań, np. obecność sali gimnastycznej oraz równomierne rozmieszczenie wybranych placówek wokół centrum województwa (Strzelczyk, 1995). Szkoły wybrano w porozumieniu z Kuratorium Oświaty i Wychowania w Poznaniu. Kolejne serie badań kontynuowano dokładnie w tych samych miejscowościach.

3.1. Podmiot badań

Badaniami bezpośrednimi objęto dzieci w wieku 7 - 15 lat ze szkół podstawowych (1986, 1996, 2006, 2016) oraz gimnazjalnych (2006, 2016). W roku 1986 zbadano 1417 chłopców i 1326 dziewcząt, w 1996: 979 chłopców i 947 dziewcząt w 2006: 871 chłopców i 843 dziewcząt oraz w 2016: 1189 chłopców i 1105 dziewcząt. Łącznie zbadano 4531 chłopców i 4332 dziewcząt (n = 8863).

Dzieci sklasyfikowano w grupach wieku na podstawie wieku kalendarzowego, stanowiącego różnicę pomiędzy datą badania a datą urodzenia. Przyjęto, że grupę wieku wyznacza środkowy punkt, i tak dzieci 7-letnie obejmowały przedział wiekowy od 6,50 do 7,49, 8-letnie od 7,50 do 8,49 i dalej analogicznie do 15-letnich od 14,50 do 15,49 lat.

W celu przeprowadzenie bardziej szczegółowych analizy dokonano podziału badanych na 3 grupy wieku (a) 7 do 9 lat – okres młodszego wieku szkolnego u obu płci; (b) 10 do 12 lat – początek i środek okresu dojrzewania (większość dziewcząt) i początek okresu dojrzewania (większość chłopców); oraz (c) 13 do 15 lat – okres młodzieńczy (większość dziewcząt), po skoku pokwitaniowym (większość chłopcy). Podział taki wynikał również z podobnej struktury stosowanej w systemie edukacji szkolnej w Polsce.

Z badań byli włączani uczniowie, których rodzice nie wyrazili zgody na uczestnictwo w pomiarach oraz ci, którzy posiadali długotrwałe zwolnienia lekarskie z obligatoryjnych zajęć z wychowania fizycznego. W analizach nie uwzględniono także wyników dzieci uczęszczających do klas specjalnych będących częścią badanych oddziałów.

3.2. Procedury badań

Badania realizowane były każdorazowo podczas lekcji wychowania fizycznego, przy współpracy z dyrekcją szkoły oraz nauczycielami wychowania fizycznego. Wszystkie pomiary wykonywane były w godzinach zajęć szkolnych w salach gimnastycznych, przez zespół badawczy, składający się z pracowników Katedry Teorii i Metodyki Sportu oraz Katedry Antropologii i Biometrii AWF w Poznaniu. Przyjęte, znormalizowane procedury były kontynuowane w kolejnych terminach, aby zachować logiczną ciągłość porównań oraz możliwość analizowania zmian.

W pierwszej kolejność zbierano całą klasę w celu sprawdzenia obecności oraz ustalenia kolejności alfabetycznej zebranych, dzięki czemu podczas wykonywania testów uczniowie podchodzili do kolejnych prób w tej samej kolejności. Następnie przedstawiono uczniom cel badań oraz prezentowano i opisywano wszystkie czynności, które będą wykonywane, w celu wdrożenia zasady świadomego i aktywnego uczestnictwa oraz wzmocnienia procesów motywacyjnych.

W dalszej kolejności dokonywano pomiarów wybranych cech somatycznych, po których przeprowadzano znormalizowaną rozgrzewkę i wykonywano poszczególne testy sprawności fizycznej zgodnie z przyjętą metodyką oraz poziomem trudności. Po zakończeniu pomiarów badani udawali się do klasy, w której wypełniali kwestionariusz ankiety w obecności przeszkolonego ankietera.

3.2.1 Pomiar cech somatycznych

W celu dokonania charakterystyki poziomu rozwoju somatycznego zastosowano szeroki zakres pomiarów antropometrycznych, które wykonano zgodnie z obowiązującymi w antropometrii zasadami (Martin i Saller 1975). Przy użyciu antropometru (GPM, Switzerland) zmierzono wysokość ciała, a wynik podawano z dokładnością 0,1 cm. Masę ciała zmierzono z dokładnością do 0,1 kg za pomocą wagi lekarskiej (Lubelskie Fabryki Wag, Polska) w 1986 r. oraz używając wag elektronicznych w kolejnych badaniach (Wagi Wielkopolska, Polska, badania 1996 i 2006; Tanita, Japonia, badanie 2016).

W dalszej kolejności, na podstawie wyników wysokości i masy ciała wyliczono wskaźnik Body Mas Index (BMI) podstawiając dane do wzoru: BMI = masa ciała [kg] / wysokość ciała [m^2]. Na tej podstawie przy użyciu punktów odcięcia (*cut off*) specyficznych dla wieku i płci według International Obesity Task Force (IOTF) dokonano podziału na następujące podgrupy stanu odżywienia: niedowaga: duża, umiarkowana, łagodna; normalna masa ciała, nadwaga, otyłość (Cole i wsp., 2000, 2007).

3.2.2 Pomiar zdolności motrycznych

W celu określenia poziomu wybranych elementów sprawności fizycznej przyjęto do realizacji i wykonano 5 testów sprawności: bieg na 5 metrów, wyskok dosiężny, skłon tułowia w przód, bieg „po ósemce" oraz zmodyfikowany 5 minutowy step-test Harwardzki.

Prędkość biegowa na dystansie 5 m [m/s]

Do pomiaru czasu biegu na dystansie 5 m z nabiegu 0,5m (celem nabiegu było wyeliminowanie wpływu czasu reakcji na bodziec akustyczny) wykorzystano układ fotokomórek laserowych (PFL-20 Kabid-Zopan, Polska w 1986, 1996, 2006; Witty Microgate, Włochy w 2016) w układzie analogowym rejestrujący wyniki z dokładnością do 0,001 sek. Stosowano wyłącznie start wysoki. Badany rozpoczynał bieg po komendzie „start". Bieg wykonywano dwa razy. Do zestawień kwalifikowany był lepszy wynik (Wachowski i wsp., 1987). Uzyskany wynik posłużył do wyznaczenia prędkości wg. wzoru:

$$V=s/t$$

gdzie: V – prędkość [m/s] s – droga [m] t – czas [s]

Skoczność - wyskok dosiężny [cm]

Za pomocą wyskoku dosiężnego określano poziom maksymalnej mocy kończyn dolnych – skoczność. Badany stawał bokiem do tablicy z centymetrową podziałką i zaznaczał wyprostowaną i uniesioną w górę ręką wysokość dosiężną. Następnie wykonywał z zamachem energiczny wyskok w górę zaznaczając palcami ręki najwyższy punkt wyskoku na tablicy. Różnica między wysokością wyskoku a wysokością dosiężną stanowi poszukiwaną wielkość, podawaną z dokładnością do 1,0 cm. Badany wykonywał 3 próby, w analizie uwzględniono wynik najlepszy (Wachowski i wsp. 1987).

Głębokości skłonu (gibkość) - skłon tułowia w przód [cm]

Badany podczas pomiaru głębokości skłonu w przód stawał bez butów na podwyższeniu (wysokość = 32 cm, długość = 35 cm, szerokość = 45 cm), na linii stóp skala wynosiła 50 cm a wartości rosły w dół. Badany utrzymując stopy zwarte oraz kończyny dolne w stawach kolanowych wyprostowane, otrzymywał polecenie wznosu ramion przodem w górę a następnie wykonanie możliwie najgłębszego skłonu w przód. Badany zaznaczał palcami rąk najniższy punkt na przymocowanej do podwyższenia podziałce. Wartości na podziałce rosły w dół. Test powtarzano dwukrotnie, do analizy wykorzystano lepszy wynik (Wachowski i wsp. 1987).

Zwinność - bieg „po ósemce" [s]

Wynik określany był na podstawie uzyskanego czasu w biegu „po ósemce" mierzonego z dokładnością do 10^{-1}s. Badany stawał w połowie odległości (2,5 m) między dwoma tyczkami treningowymi, które oddalone były od siebie o 5 m i posiadały wysokość 1,2 m. Ćwiczenie polegało na jak najszybszym, trzykrotnym przebiegnięciu toru opisującego „ósemkę". Pierwszy skręt odbywał się w prawo. Czas mierzono stoperem (0,01 s, 1986, CAENAHOB, C.C.C.P./SLAVA, Rosja, 1986; Casio HS-80TW Lap Stop-watch, Japonia, 1996, 2006, 2016). Test powtarzano dwukrotnie, do analizy wykorzystano lepszy wynik (Fleishman 1964; Pawlak i Sarna 1982).

Wytrzymałość ogólna - zmodyfikowany 5 minutowy step-test Harwardzki [pkt.]

Do oszacowania poziomu wytrzymałości ogólnej (wydolności) wykorzystano zmodyfikowany step-test Harwardzki. Badany w czasie 5 minut wchodził na stopień o wysokości 30 cm w rytmie 30 wejść i zejść na minutę. Po ukończeniu ćwiczenia, w czasie pomiędzy 60 i 120 sekundą, wykonywano pomiar tętna za pomocą czujnika elektronicznego zakładanego na palec wskazujący w 1986 i 1996 (jednostka analogowa N-327-5, konstrukcja Zakładu Pomocy Naukowych AWF Poznań) oraz za pomocą czujnika elektronicznego zakładanego na płatek ucha w 2006 i 2016 roku (C812 jednostka analogowa z oprogramowaniem Tester, Politechnika Poznańska). Uzyskany wynik tętna służył do obliczenia wskaźnika wydolności fizycznej wyrażonego w punktach wg wzoru:

$$Ww = \text{czas pracy w sekundach} \times 100/5{,}5 \times p$$

gdzie: Ww – wskaźnik wydolności, p – wartość zmierzonego tętna po wysiłku

W celu interpretacji wyników przyjęto następujące normy poziomu wydolności dla omawianego wskaźnika:

≥ 60 bardzo wysoka, 50.0-60.0 wysoka, 40,0-50,0 średnia, 30,1-40,0 niska, <30 upośledzona (Gruszczyński i wsp. 1974; Mazur i wsp. 1975).

3.3. Czynniki środowiskowe

W celu zebrania informacji dotyczących środowiska badań zastosowano metodę sondażu diagnostycznego realizowanego techniką badań ankietowych, za pomocą, których zebrano informację odnośnie czynników środowiska rodzicielskiego (ankieta dla rodziców), szkolnego (ankieta dla dyrekcji) oraz badanych dzieci (ankieta dla dzieci). Dodatkowo wykorzystane zostały dane z Rocznika statystycznego za rok 1986, 1996, 2006 oraz 2016. W badaniach przeprowadzonych w roku 1996, 2006 i 2016 zastosowano kwestionariusze ankiet opracowane przez Strzelczyka (1995) i wykorzystane w pierwszej turze badań w 1986 roku. Użyte kwestionariusze ankiet spełniały wymogi trafności i rzetelności. Informacje o wystąpieniu pierwszej miesiączki uzyskano metodą retrospektywną na podstawie wywiadu. Każda z dziewcząt była indywidualnie pytana przez członka personelu badawczego płci żeńskiej o to, czy menarche wystąpiła (tak), czy też jeszcze nie (nie), z zachowaniem intymności.

Na wykonanie badań każdorazowo uzyskano zgodę Kuratorium Oświaty w Poznaniu (wcześniej Kuratorium Oświaty i Wychowania w Poznaniu) oraz dyrektorów poszczególnych szkół zgodnie z obowiązującymi w poszczególnych latach wymogami. Na ostatnią serię badań uzyskano zgodę Komisji Bioetycznej przy Uniwersytecie Medycznym im. Karola Marcinkowskiego w Poznaniu nr KB nr 907/16.

3.4. Analiza statystyczna

Wykonano podstawowe analizy statystyczne: normalność rozkładu oceniano na podstawie testu Shapiro – Wilka, obliczono średnią arytmetyczną [M], odchylenie standardowe [SD], błąd odchylenia standardowego [SE] oraz medianę [ME] dla poszczególnych grup wieku kalendarzowego odpowiednio w każdej serii badań dla chłopców i dziewcząt. Na ich podstawie opracowano podstawowe charakterystyki oraz stworzono wykresy obrazujące kierunek zmian w czasie.

Następnie w celu porównań między grupami i terminami zastosowano analizę kowariancji (ANCOVA) z wyłączeniem zmiennych współwystępujących takich jak wiek

i wiek^2, która koryguje odpowiednio potencjalne liniowe i nieliniowe efekty rozkładów wieku kalendarzowego. Zastosowano porównania post hoc między poszczególnymi seriami, skorygowane o porównania wielokrotne (Bonferroni). Dodatkowo w artykule 5 w celu „uchwycenia" ewentualnych zależności pomiędzy testami sprawności fizycznej i BMI zostały zastosowane liniowe i nieliniowe modele regresji, gdzie testy sprawności były zmienną zależną, wskaźnik BMI zmienną niezależną w modelu liniowym, natomiast wskaźnik BMI i BMI^2 były zmiennymi niezależnymi w modelu kwadratowym.

Wszystkie analizy statystyczne wykonano przy użyciu programu Statistical Package for the Social Sciences (SPSS) dla systemu Windows (wersja 22.0, IBM SPSS, Chicago, IL).

4. Wyniki oraz ich omówienie

Rozdział podzielono na pięć podrozdziałów zgodnie z problematyką podjętą w kolejnych opublikowanych artykułach wchodzących w skład cyklu. Uwzględniono w nich główne wyniki przeprowadzonych obserwacji, które nawiązywały do postawionych pytań badawczych oraz wyznaczonego celu. Wszystkie informacje przedstawione poniżej oraz nawiązania do tabel i rycin w każdym podrozdziale odnoszą się do treści zawartych w oryginalnych artykułach. Każdy z pięciu podrozdziałów kończy się krótkim podsumowaniem.

Publikacja 1.

Secular change in height and weight of rural school children and youth in west-central Poland: 1986 to 2016. American Journal of Human Biology, 2021;33(2):e23461

Celem pracy było porównanie zmian wysokości i masy ciała dzieci w wieku 7-15 lat w czterech terminach badań prowadzonych w odstępach dekadowych od 1986 do 2016.

W pracy przedstawiono wyniki analiz uwzględniających:

a) podział na pojedyncze grupy wieku (7, 8, 9, …, 15 lat),
b) podział na trzy grupy wieku (7-9, 10-12, 13-15 lat),
c) oraz zmiany pomiędzy kolejnymi dekadami (1986-2016, 1986-1996, 1996-2006, 2006-2016).

Ad a) Analiza danych dotyczących wysokości ciała w pojedynczych grupach wieku, wykazała, że najwyższe były dzieci i młodzież w ostatniej serii badań (2016), a trend ten obserwowany był u obu płci. W grupie chłopców siedmio- i ośmioletnich zaobserwowano brak różnic między latami 1986 a 1996 oraz między 2006 a 2016. W kolejnych grupach wieku chłopców, w następnych dekadach obserwowano systematyczne, niemalże liniowe zwiększanie się wysokości ciała (Rycina 2A). W grupie dziewcząt wyniki nie układały się w tak regularny sposób jak u chłopców. Pomiędzy rokiem 1996 a 2006, wyłączając siedmiolatki, nie zaobserwowano przyrostu wysokości ciała w kolejnych grupach wieku. Dziewczęta badane w ostatniej dekadzie były średnio wyższe od rówieśniczek z pozostałych terminów obserwacji (Rycina 3A).

W odniesieniu do masy ciała chłopców zaobserwowano wzrost zarejestrowanych wartości w wszystkich terminach badań, z wyłączeniem grupy ośmiolatków w dekadzie 2006 - 2016. Największe średnie różnice w poszczególnych grupach wieku odnotowano pomiędzy skrajnymi terminami (Rycina 2B). W grupie dziewcząt zaobserwowano większą zmienność badanej cechy w kolejnych terminach badań, jednak kierunek zmian był taki sam jak u chłopców. Najwyższą masę ciała zanotowano u badanych dziewcząt w roku 2016 a najniższą w 1986 roku. Dynamika przyrostów ulegała zmniejszeniu po 13 roku życia (Rycina 3B).

Ad b) Przeprowadzona analiza wykazała, że zmienność wysokości i masy ciała różni się w sposób istotny statystycznie ($P < 0,001$) pomiędzy opisanymi trzema grupami wieku. Porównania wielokrotne pomiędzy analizowanymi grupami (post-hoc) wykazały następujące zależności w grupie chłopców 2016 > 2006 > 1996 > 1986. (Tabela 1). W grupie dziewcząt zmienność wysokość ciała była podobna w trzech grupach wieku 2016 > 2006 > 1996 > 1986 jednakże porównania grupami pomiędzy poszczególnymi terminami nie były jednoznaczne (Tabela 2).

Zmiany masy ciała we wszystkich trzech grupach wieku chłopców również nie przebiegały w sposób liniowy w kolejnych dekadach obserwacji. Występowała następująca zmienność 2016 > 2006 > 1996 > 1986, za wyjątkiem grupy 7-9 lat (2016=2006>1996>1986) (Tabela 1). W grupie dziewcząt nie zaobserwowano wspólnego kierunku zmian. W każdej grupie wieku przyrosty obserwowane były pomiędzy różnymi dekadami (Tabela 2).

Ad c) Analizując zmiany międzydekadowe w trzydziestoletnim okresie zaobserwowano podobne kierunki oraz wielkości zmian wysokości i masy ciała w grupach wieku 7-9 i 10-12 lat wśród obu płci. W ostatniej grupie wieku analogiczne zmiany są większe w grupie chłopców (Tabela 3). Wykazano, że największa dynamika przyrostów wysokości i masy ciała we wszystkich grupach wieku chłopców wystąpiła pomiędzy 1996 a 2006 rokiem, a różnice były istotne statystycznie. Najmniejsze przyrosty obserwowano w ostatniej dekadzie badań. W grupie dziewcząt 7-9 i 13-15 letnich największe przyrosty wystąpiły pomiędzy 1996 a 2006 rokiem, natomiast w grupie 10-12 lat w ostatniej dekadzie badań, różnice również był istotne statystycznie.

Podsumowanie

Szczegółowa analiza różnic w przyrostach badanych cech wykazała, że zarówno wysokość jak i masa ciała zwiększyła się w obserwowanym 30 letnim okresie badań, a wielkości tych zmian były istotne statystycznie. Przyrosty nie przebiegały w sposób liniowy i różniły się w ciągu trzech dziesięcioleci oraz pomiędzy grupami dziewcząt i chłopców.

Publikacja 2.

Weight Status of Rural School Youth in Poland: Secular Change 1986-2016 Anthropologischer Anzeiger;. 2022 79(1):43–56

Celem pracy było przedstawienie zmienności wskaźnika BMI u dzieci w wieku 7-15 lat w czterech terminach badań prowadzonych w odstępach dekadowych od 1986 do 2016.

Podobnie jak w pierwszej pracy, analizy obejmowały zmienność BMI:

a) w grupach wieku kalendarzowego,
b) pomiędzy trzema grupami wieku i poszczególnymi terminami badań,
c) z uwzględnieniem grup stanu odżywienia - niedowaga, nadwaga i otyłość.

Ad a) W pracy wykazano, że w kolejnych dekadach w poszczególnych grupach wieku, zaobserwowano trend, związany ze zwiększaniem się wartości wskaźnika BMI. Przyrosty pomiędzy skrajnymi terminami przyjmowały bardziej liniowy i dodatni kierunek w grupie chłopców niż w grupie dziewcząt.

Ad b) Porównania w trzech grupach wieku, i względem płci, wykazały nieliniową zmienność wartości wskaźnika BMI pomiędzy kolejnymi grupami i terminami. W każdej grupie wieku chłopców wartości BMI w ostatnich dwóch terminach badań (c i d) nie wykazywały zmienności i były wyższe niż w roku 1996 (b) i 1986 (a) z wyjątkiem chłopców w wieku 7–9 lat, u których BMI w 1996 r. jest istotnie wyższe niż w 1986 roku (Tabela 1). W grupie dziewcząt wartości różniły się w poszczególnych grupach wieku, największą zmienność odnotowano w grupie wieku 10-12 lat. Występowała jednak tendencja wskazująca, że zmienność wyników w roku 2006 (c) i 2016 (d) była każdorazowo wyższa niż w latach poprzednich (b i a) (Tabela 1). Wartości BMI w obu grupach płci oraz we wszystkich grupach

wieku pomiędzy skrajnymi terminami różniły się istotnie statystycznie ($p < 0.001$) (Tabela 2).

Ad c) W kolejnym etapie pracy dokonano analizy ze względu na grupy stanu odżywienia. W okresie objętym badaniem liczba dzieci z niedowagą w grupie chłopców zmniejsza się. Jednocześnie obserwuje się regularne zwiększanie się liczby chłopców z nadwagą i otyłością we wszystkich badanych grupach wieku. Częstość występowania nadwagi i otyłości jest istotnie większa w 2006 i 2016 w porównaniu do 1996 i 1986 roku (Tabela 3).

Wśród badanych dziewcząt występowała niewielka liczba osób z niedoborową masą ciała, i podobnie jak w przypadku chłopców, procent dzieci z niedowagą spadał w kolejnych terminach badań. W grupach wieku 7-9 i 10-12 lat zaobserwowano procentowy wzrost nadwagi i otyłości w kolejnych dekadach. W ostatniej grupie wieku kierunek zmian był taki sam, jednak wartości przyrostów były niższe (Tabela 3).

Podsumowanie

Zmiany wskaźnika BMI były istotne statystycznie i występowała tendencja zwiększania się jego wartości w kolejnych terminach obserwacji. Szczegółowa analiza uwzgledniająca grupy stanu odżywienia wykazała tendencję do zmniejszania się występowania niedowagi szczególnie pomiędzy 1986 a 1996 oraz do wzrostu nadwagi i otyłości szczególnie pomiędzy 2006 a 2016 rokiem. Wyniki nie ulegały zmianom w sposób liniowy i różniły się w ciągu trzech dziesięcioleci oraz pomiędzy grupami dziewcząt i chłopców.

Publikacja 3.

Age at menarche among rural school youth in west-central Poland: variation with weight status and population growth. Anthropological Review, 2021 84(1), 51-58

Celem pracy była próba oszacowania wieku występowania pierwszej miesiączki wśród dziewcząt z regionu wiejskiego Wielkopolski w grupie badanych z 2016 roku oraz porównanie wieku menarche w grupach stanu odżywienia oraz względem zmian liczby mieszkańców w obserwowanych miejscowościach.

Obserwacji poddano wyniki 1146 dziewcząt w wieku 7-16 lat pochodzących z 10 miejscowości wiejskich. W pracy dokonano analiz z uwzględnieniem:

a) całej grupy;
b) podziału na grupy stanu odżywienia (niedowaga, normalna masa ciała, nadwaga);
c) podziału ze względu na zmiany liczby mieszkańców - gdzie jedną grupę stanowiły miejscowości, w których zaobserwowano wzrost liczby ludności, drugą natomiast stanowiły miejscowości, w których wzrost był niewielki lub w ogóle nie wystąpił,
d) podziału na grupy staniu odżywienia i przyrost populacyjny (z analizy wykluczono dziewczęta z niedowagą, ze względu na zbyt małą liczebność).

Ze względu na ograniczenia w wynikach badań analizę przeprowadzono tylko dla dziewcząt z 2016 roku.

Ad a) Wykonana analiza pokazała, że mediana (±SE) wieku pierwszej miesiączki w badanej populacji wynosi 13,25±0,20 lat.

Ad b) W grupach stanu odżywienia pierwsza miesiączka występuje średnio najwcześniej wśród dziewcząt z nadwagą - 13,06±0,32 lat, następnie w grupie z prawidłową masą ciała - 13,25±0,37 lat, a najpóźniej w grupie dziewcząt z niedowagą - 13,81±0,41lat. Różnica wieku wystąpienia pierwszej miesiączki pomiędzy grupami z niedowagą i nadwagą przejawiała tendencję do istotności, natomiast pozostałe porównania parami nie były istotne statystycznie (Tabela 1).

Ad c) Wykazano również, że jednym z czynników wpływających na zmianę czasu wystąpienia pierwszej miesiączki może być zmiana liczby mieszkańców w badanej populacji. W grupie miejscowości, w której nastąpił znaczny wzrost liczby populacji mediana wyniosła 12,58±0,44 lat i odpowiednio dla miejscowości, w których nie zaobserwowano wzrostu wyniosła 13,65±0,14 lat (Tabela 2).

Ad d) W grupie dziewcząt z gmin o większym przyroście liczby mieszkańców mediana wieku menarche wynosiła 12,12±0,49 lat u dziewcząt z nadwagą i 12,54±0,15 lat u dziewcząt z prawidłową masą ciała. Odpowiednie analizy dla grupy z niskim/brakiem wzrostu wskazały, że mediana wynosiła 13,46±0,40 lat dla dziewcząt z nadwagą i 13,62±0,18 lat dla dziewcząt o normalnej masie ciała.

Podsumowanie

Stwierdzono, że mediana wieku pierwszej miesiączki była wcześniejsza w grupie osób z nadwagą, w porównaniu z pozostałymi grupami. Zaobserwowano wpływ zmiany wielkości liczby mieszkańców w czasie na wiek występowania pierwszej miesiączki.

Publikacja 4.

Physical Fitness of Rural Polish School Youth: Trends between 1986 and 2016 Journal of Physical Activity and Health, 2021 28;18(7):789-800

Celem badań była ocena wielkości i kierunku zmian poziomu wybranych zdolności motorycznych u dzieci w wieku 7-15 lat w czterech terminach badań prowadzonych w odstępach dekadowych od 1986 do 2016.

Podobnie jak w pierwszym i drugim artykule przeprowadzone analizy wyników dotyczące zmienności poziomu wybranych zdolności motorycznych uwzględniały porównania:

a) w grupach wieku kalendarzowego;
b) pomiędzy trzema grupami wieku i poszczególnymi terminami badań;
c) pomiędzy poszczególnymi dekadami obserwacji.

Ad a) Prędkość biegu (Rycina 1A) wzrastała średnio w kolejnych grupach wieku chłopców. Taki sam kierunek zmian obserwowano w grupie dziewcząt od 7 do 12 roku życia, po czym następował okres stabilizacji (plateau). Zwinność (Rycina 1B) wykazywała podobny kierunek zmian jak gibkość, związane one były z wiekiem oraz płcią badanych. Należy zauważyć, że niższy czas wskazuje na lepszy wynik. Wyniki w teście skoczności (Rycina 1C) wzrastały średnio w kolejnych grupach wieku od 7 do 15 lat u obojga płci. Z kolei poziom gibkości (Rycina 1D) wzrastał wraz z wiekiem od 7 do 11 roku życia u obojga płci, następnie obserwowano dynamicznie przyrosty po 13 roku życia u chłopców i rok wcześniej u dziewcząt. Wyniki wskaźnika wydolności (Rycina 1E) układają się w sposób nieregularny w grupach wieku chłopców. U dziewcząt wartość wskaźnika wydolności obniża się w kolejnych grupach wieku niezależnie od terminu obserwacji.

Ad b) Wyniki obserwowanych zdolności motorycznych na przestrzeni 30 lat różniły się istotnie statystycznie w trzech grupach wieku wśród chłopców, z wyjątkiem wskaźnika

wydolności w grupie 13-15 lat. Istotne różnice widoczne były również w trzech grupach wieku dziewcząt, wyjątek stanowiły wyniki skoczności w grupie wieku 13-15 lat. Wielkości efektów (η^2_p) mówiące o sile zjawiska były umiarkowane w dla wyników prędkości biegowej, a w przypadku pozostałych obserwowanych zdolności motorycznych były niskie u obojga płci (Tabela 1 i Tabela 2).

Ad c) Analiza zmian międzydekadowych wykazała regres zdolności do rozwijania prędkości biegu w objętym badaniami trzydziestoleciu (Tabela 3). Prędkość biegowa (Rycina 2A) obniżała się w latach 1986-2016 u chłopców i dziewcząt. Szczegółowe obserwacje wykazały, że regres tej zdolności latach 1986-1996 ($P < 0,05$), widoczny jest w grupie chłopców a pomiędzy 1996 a 2006 w grupie dziewcząt.

Wyniki w teście zwinności wzrastają (krótszy czas wykonania próby) istotnie pomiędzy 1986 a 2016 r., z wyjątkiem dziewcząt w wieku 10–12 lat (Rycina 2B). Poziom zwinności wzrasta istotnie ($P < 0,05$) w latach 1986-1996 u chłopców i dziewcząt w 3 grupach wiekowych. Natomiast pomiędzy pozostałymi dekadami obserwacji zmiany nie były istotne statystycznie za wyjątkiem grupy chłopców w wieku 13 – 15 lat pomiędzy 1996 a 2006 rokiem.

Analiza wyników testu skoczności w latach 1986-2016 wykazała, że w dwóch młodszych grupach wieku chłopcy i dziewczęta uzyskiwali podobne rezultaty, w odróżnieniu od najstarszych grup, w których przyrosty były większe u chłopców a znikome u dziewcząt (Rycina 2C). W podziale na 3 grupy wiekowe u chłopców zaobserwowano zwiększanie się wyników w teście skoczności pomiędzy okresem 1986 a 1996 ($P < 0,05$). W dekadzie 1996 – 2006, wartości nie wykazywały jednego kierunku zmian, a następnie obniżały się między 2006 a 2016 ($P < 0,05$). U dziewcząt w grupach wieku 7-9 obserwowano istotne statystycznie przyrosty poziomu skoczności w latach 1986-1996, a w grupie 10-12 po istotnych przyrostach w latach 1986-1996 wartości obniżały się dekadzie 1996-2006 ($P < 0,05$). W pozostałych dekadach zmiany byłyby nieistotne statystycznie. W grupie 13-15 lat zmiany były niewielkie i nieistotne statystyczne w całym obserwowanym okresie badań.

W okresie objętym obserwacją poziom gibkości obniżył się istotnie statystycznie we wszystkich grupach wieku. Zmiany te były większe w grupie chłopców niż w grupie dziewcząt (Rycina 2D). W latach 1986-1996 oraz 1996-2006 zarówno u chłopców, jak i dziewcząt obserwowano obniżanie się wyników ($p < 0,05$ w wieku 7–9 i 10–12 lat). W latach 2006-2016 poziom gibkość w grupie dziewcząt zwiększył się w sposób istotny

statystycznie wyłącznie w grupie wieku 7–9 lat ($p < 0,05$), podczas gdy u chłopców nadal obserwowano obniżanie się wyników ($p < 0,05$, w wieku 10–12 i 13–15 lat).

Wartości wskaźnika wydolności zwiększa się nieznacznie (brak istotności statystycznej) u dziewcząt w wieku 7–9 i 10–12 lat, jednakże wzrastała istotnie u dziewcząt w wieku 13–15 lat w latach 1986–2016 ($p < 0,05$). U chłopców poziom wydolności obniżył się we wszystkich grupach wieku przy czym istotnie w grupie 10–12 lat (Rycina 2E). Obserwowano dużą zmienność wartości wskaźnika wydolności pomiędzy kolejnymi terminami badań. Poziom wydolności obniżył się u chłopców ($P < 0,05$) i dziewcząt w wieku 7–9 i 10–12 lat, natomiast wzrastał u chłopców i dziewcząt ($P < 0,05$) w wieku 13–15 lat w latach 1986-1996. W kolejnej dekadzie wskaźnik wzrastał we wszystkich grupach dziewcząt, w tym w sposób statystycznie istotny w przedziałach wieku 7–9 i 10–12 lat. U chłopców z kolei zaobserwowano zmniejszanie się omawianego wskaźnika w wieku 10–12 i 13–15 lat oraz zwiększanie w grupie 7-9 lat jednak zmiany nie były istotne statystycznie. W latach 2006-2016 zmiany nie były istotne statystycznie, poziom wydolności obniżał się u dziewcząt a wzrastał u chłopców we wszystkich grupach wieku.

Podsumowanie

Stwierdzono, że podobnie jak w przypadku cech somatycznych nie zaobserwowano jednoznacznej tendencji w kierunku zmian wszystkich obserwowanych zdolności motorycznych.

Publikacja 5.

Relationship between BMI and physical fitness of Polish School Youth: Trends between 1986 and 2016 Acta Kinesiologica 2021, 15 (2):134-143

Cel pracy zakładał zbadanie relacji pomiędzy wskaźnikiem BMI (wyniki wcześniej opisane w artykule 2.), a wybranymi zdolnościami motorycznymi (wyniki przedstawione w artykule 4.).

W pracy przedstawiono wyniki analiz uwzględniających:

a) porównanie w grupach wieku wyników poszczególnych testów sprawności fizycznej z uwzględnieniem grup stanu odżywienia oraz poszczególnych terminów badań,
b) analizę regresji dla każdego testu sprawności z BMI z uwzględnieniem płci przy użyciu liniowych i nieliniowych modeli kwadratowych.

Ad a) Wyniki testów sprawności różniły się w sposób istotny statystycznie pomiędzy grupami stanu odżywienia zarówno u chłopców jak i u dziewcząt. Wyjątek stanowiła gibkość w grupie chłopców w wieku 7-9 lat oraz u chłopców i dziewcząt w wieku 10-12 lat. Różnice pomiędzy kolejnymi terminami obserwacji były również istotne statystycznie, za wyjątkiem wskaźnika wydolności w grupie chłopców 7-9 i 13-15 lat oraz skoczności w grupie dziewcząt 13-15 letnich. Jednak interakcje pomiędzy grupami stanu odżywienia a terminami badań nie różniły się na ogół istotnie, i nie wykazywały wyraźnej tendencji pomiędzy kolejnymi testami sprawności, u obu płci (Tabela 1).

W grupie chłopców porównania post hoc (Tabela 2) wskazywały na uzyskiwanie niższych wyników we wszystkich testach sprawności, z wyjątkiem gibkości dzieci i młodzieży z nadwagą i otyłością w porównaniu z dziećmi o masie ciała w normie i szczupłymi. Porównania wyników w zakresie poziomu zdolności motorycznych w grupach stanu odżywienia w kolejnych terminach obserwacji nie wykazują wspólnego kierunku zmian, z wyjątkiem prędkości. Wyniki w teście szybkości były na ogół podobne w latach 1986-1996 oraz 2006-2016, ale były wyższe w dwóch pierwszych terminach obserwacji w porównaniu do dwóch ostatnich. Wartości wskaźnika wydolności, podobnie jak prędkość biegu, zwiększyły się w dwóch młodszych grupach wiekowych w 1986 roku w odróżnieniu od najstarszej grupy.

Wśród dziewcząt porównania post hoc (Tabela 3) wskazywały na konsekwentnie niższe wyniki w zakresie skoczności w grupie z nadwagą i otyłością w wieku 10-12 i 13-15 lat, podczas gdy wyniki dzieci szczupłych i o masie ciała w normie charakteryzowały się różnymi kierunkami zmian. Prędkość biegu u dziewcząt miała takie same kierunki zmian jak u chłopców. Wyniki w innych testach sprawności w ramach grup stanu odżywienia były podobnie jak u chłopców, a kierunki zmian nie przebiegały w taki sam sposób, w kolejnych terminach obserwacji.

Ad b) Wyniki analiz regresji podsumowano w tabelach 4 (chłopcy) i 5 (dziewczęta). Większość z obserwowanych regresji miało bardzo niską wyjaśnioną wariancję (R^2), jednak

kilka z nich było istotnych. Zależności pomiędzy BMI a wynikami sprawności również różniły się w czterech terminach obserwacji. Niemniej jednak współczynniki kwadratowe były istotne w niektórych modelach, co wskazuje, że związek pomiędzy BMI a konkretnym testem sprawności był krzywoliniowy. Sugeruje to, że wyższe wyniki osiągały zazwyczaj dzieci i młodzież z BMI w średnim zakresie rozkładu, podczas gdy wyniki osób znajdujących się w dolnym i górnym zakresie rozkładu BMI były niższe. Było to widoczne w przypadku związków pomiędzy BMI a prędkością biegu, zwinnością i skocznością w badaniu z 1986 r., z wyjątkiem dziewcząt w wieku 7-9 lat. Z drugiej strony, zaobserwowano zależność krzywoliniową we wszystkich czterech terminach badań dla wszystkich obserwowanych zdolności motorycznych, z wyjątkiem wskaźnika wydolności wśród chłopców w wieku 13-15 lat.

Podsumowanie

Stwierdzono, że wyniki analizy regresji wykazywały zależność krzywoliniową pomiędzy BMI a wynikami w poszczególnych testach sprawności fizycznej, w większym stopniu u chłopców niż u dziewcząt. Taki wynik wskazuje, że zazwyczaj wyższe rezultaty uzyskiwały dzieci i młodzież z BMI w średnim zakresie rozkładu.

5. Dyskusja

Przedstawiony cykl publikacji opisuje zagadnienia związane z kierunkami zmian w zakresie wysokości, masy ciała, wskaźnika BMI, wieku pierwszej miesiączki i poziomu sprawności fizycznej oraz występowania zależności pomiędzy grupami stanu odżywienia a sprawnością fizyczną.

Dane opisywane w piśmiennictwie przedmiotu dotyczące zmienności w grupach dzieci i młodzieży polskiej prezentowane były przez różnych autorów w odmienny sposób. Niektóre z prac przedstawiają porównania dla pojedynczych grup wieku dziesiętnego, jednak dotyczą różnych przedziałów wieku np. 7,0; 8,0… 15,0 lat (Gomuła i wsp., 2015) lub 7,5; 8,5; 15,5 lat (Przewęda i Dobosz, 2003; Kowal i wsp., 2011). Inne prace prezentowały dane z uwzględnieniem określonych grup wiekowych np. 7-9, 10-12, 13-15 lat (Ignasiak i wsp., 2016). Badacze przedstawiali również analizy z perspektywy miejsca zamieszkania, prezentowane były dla całości populacji polskiej (Przewęda i Dobosz, 2003; Gomuła i wsp., 2015), poszczególnych jego regionów oraz grup społecznych (miasto – wieś), poszukując kierunków zmian oraz ich ewentualnych uwarunkowań (Krawczyński i wsp., 2003; Saczuk, 2018; Wilczewski, 2005; Wilczewski i Wilczewski, 2018).

Wysokość, masa ciała oraz wiek pierwszej miesiączki, jako zmienne uwarunkowane zarówno czynnikami środowiskowymi jak i genetycznymi w kolejnych dekadach od 1986 do 2016 wykazały podobne kierunki zmian, do tych badań, które prowadzone były w zbliżonych przedziałach czasowych dla dzieci z populacji polskiej (Przewęda i Dobosz, 2003; Gomuła i wsp. 2015). Dotyczyło to również obserwacji wykonywanych w poszczególnych miastach i regionach Polski, np. dla miasta Poznania (Krawczyński i wsp. 2000; 2003), Krakowa (Kowal i wsp. 2011; Woronkowicz i wsp., 2012), Rzeszowa (Perenc, i wsp., 2016) oraz wschodniej części Polski (Saczuk, 2018; Wilczewski, 2005; Wilczewski i Wilczewski, 2018).

Należy zwrócić jednak uwagę, że zmiany wysokości i masy ciała dzieci z dziesięciu miejscowości wiejskich w dwóch pierwszych dekadach obserwacji, prezentowane w niniejszym autoreferacie były porównywalne z badaniami ogólnopolskimi prowadzonymi w latach 1988-2012 (Gomuła i wsp., 2015), natomiast w porównaniu z badaniami prowadzonymi w latach 1989-1999 (Przewęda i Dobosz, 2003) zmiany były generalnie mniejsze. Pozwala to na stwierdzenie, że przyrosty odnotowane w czasie czterech terminów obserwacji następowały w nieliniowy sposób, a jednym z czynników wpływających na nie mógł być region zamieszkania.

Wartość wskaźnika BMI zwiększała się w kolejnych terminach badań zarówno u dziewcząt jak i u chłopców we wszystkich grupach wieku. Uzyskane wyniki z roku 2016 w porównaniu do danych referencyjnych dla dzieci i młodzieży z populacji polskiej z 2010 roku (Kaługa i wsp., 2011) były zbliżone u chłopców w wieku 7 i 8 lat. Wyniki dla kolejnych grup wieku populacji wiejskiej Wielkopolski przewyższały mediany z badań ogólnokrajowych, a zjawisko to obserwowane było w większości grup dziewczęcych. Jednakże wyniki dzieci w wieku 10-15 lat były zbliżone do wyników prezentowanych dla populacji miejskiej i wiejskiej w województwie wielkopolskim w latach 2009-2010 (Kaczmarek i wsp., 2011).

Wykazano, że częstość występowania nadwagi i otyłości wzrosła we wszystkich terminach obserwacji i była znacznie wyższa w roku 2006 i 2016 w porównaniu do 1986 i 1996. Zaobserwowane kierunki zmian nadwagi i otyłości były zgodne z ogólnopolskimi danymi porównawczymi, w których badania prowadzono w latach 1969, 1978, 1988 i 2012 (Gomuła i wsp., 2015), w 2001 roku (Małecka-Tandera i wsp., 2005) oraz w 2010 roku (Kaluga i wsp., 2011). Podobny liniowy przyrost wartości obserwowali również badacze wśród dzieci z miasta stołecznego Krakowa, w którym prowadzone były badania w latach 1971, 1983 i 2000 (Chrzanowska i wsp., 2007). Taką samą tendencję obserwowano w poszczególnych regionach naszego kraju, w województwie podlaskim w latach 1986 i 2006 (Saczuk i Wasiluk, 2014) oraz w województwie podkarpackim w latach 1998 i 2008 (Mazur i wsp., 2014).

Wyżej opisane kierunki zmian dotyczyły wszystkich grup wiekowych chłopców oraz dziewcząt 7-9 i 10-12 letnich. W grupie dziewcząt 13-15 letnich przy takim samym kierunku zmian, wielkość przyrostów była zdecydowanie niższa, czego prawdopodobną przyczyną mogło być wcześniejsze dojrzewanie dziewcząt oraz pojawiająca się świadomość dotycząca postrzegania wizerunku własnego ciała, co jest jednym z kluczowych elementów kształtujących osobowość osoby dojrzewającej (Malina i wsp., 2004).

Obserwacje wykazały, że częstość występowania niedowagi w badanej populacji była niska zarówno u chłopców jak i u dziewcząt. W kolejnych latach badań liczba dzieci w tej grupie zmalała w 2006 i 2016 roku w porównaniu do 1986 i 1996. Badacze zdecydowanie częściej opisywali problemy związane z nadwaga i otyłością, którą Światowa Organizacja Zdrowia uznała za jedną z najgroźniejszych chorób przewlekłych XXI wieku (Ng i wsp., 2014; WHO, 2000). W związku z powyższym dostęp do danych traktujących o trendach sekularnych dotyczących niedowagi, podzielonej na dużą, umiarkowaną i łagodną, jest ograniczony. Wyniki

chłopców i dziewcząt w wieku 13-15 lat z 2016 roku można odnieść jednak do danych zebranych dla dzieci miejskich i wiejskich województwa wielkopolskiego w wieku 13-18 lat prowadzonych w latach 2009-2010 (Durda, 2011). Łagodna niedowaga występowała stosunkowo częściej w 1986 roku i nieznacznie zmniejszyła się w 2006 roku wśród młodzieży w wieku 10-12 i 13-15 lat. Była ona jednak wyższa wśród wiejskich dzieci w wieku 7-9 lat w 1986 roku (chłopcy 15,6%, dziewczęta 13,4%), natomiast zmniejszyła się w 2016 roku (chłopcy 4,1%, dziewczęta 7,3%). Podobne obserwacje, dotyczące łagodnej niedowagi wśród dzieci w wieku 7-9 lat, prowadzone były w województwie podlaskim i wykazywały niższy odsetek jej występowania w 1986 roku (chłopcy 7,3%, dziewczęta 11,5%), który następnie zwiększył się nieistotnie w 2006 roku (chłopcy 8,9%, dziewczęta 12,8%) (Saczuk i Wasiluk, 2014).

Podsumowując powyższe obserwacje, w dolnej granicy zakresu wskaźnika BMI częstość występowania dużej i umiarkowanej niedowagi była bardzo niska we wszystkich czterech terminach badań zarówno u chłopców jak i u dziewcząt, natomiast częstość występowania łagodnej niedowagi była stosunkowo niska we wszystkich prowadzonych obserwacjach, z wyjątkiem chłopców i dziewcząt w wieku 7-9 lat w 1986 roku. Z drugiej strony, częstość występowania nadwagi była wyższa w 2006 i 2016 roku w porównaniu do 1986 i 1996 roku wśród chłopców i dziewcząt w trzech grupach wiekowych, podczas gdy częstość występowania otyłości była niższa. Potencjalną przyczyną może być zmiana nawyków żywieniowych oraz sedenteryjny tryb życia młodych osób.

Mediana wieku wystąpienia pierwszej miesiączki, jako czynnik służący do oceny tempa dojrzewania w obserwowanej populacji wiejskiej w 2016 roku wynosił 13,25 lat. Podobne wyniki przedstawiały dane porównawcze dla czterech regionów geograficznych Polski wykonane w 2001 roku. Dotyczyły one wieku dziewcząt wiejskich z rodzin rolników, u których mediana wynosiła 13,32 lat oraz tych mieszkających na obszarach wiejskich niebędących córkami rolników 13,17 lat (Łaska-Mierzejewska i Olszewska, 2007). W badaniach przeprowadzonych w 2012 roku w siedmiu województwach w Polsce, podczas których obserwacji poddano dziewczęta w wieku 7-18 lat z małych miast i terenów wiejskich mediana wynosiła 13,11 lat i była niższa niż w obserwowanej wiejskiej populacji (Gomuła i Kozieł, 2018).

Jednym z czynników warunkujących wiek występowania pierwszej miesiączki jest stan odżywienia. Analiza uwzględniająca grupy skategoryzowane według tego kryterium wykazała,

że w obserwowanej populacji najwcześniej dojrzewały dziewczęta z nadwagą, u których mediana wieku wyniosła 13,06 lat, później dojrzewały dziewczęta z prawidłową masą ciała 13,25 lat, a najpóźniej z grupy z niedowagą 13,34 lat. Wyniki obserwacji potwierdzały zależności, na które wskazywano w badaniach prowadzonych w innych krajach i regionach wnioskując, że dziewczęta z nadwagą dojrzewają wcześniej (Anderson i Must, 2005; Biro i wsp., 2018; Bratke i wsp., 2017; Himes i wsp., 2009; Lazzeri i wsp., 2018). W badaniach longitudinalnych prowadzonych w Poznaniu mediana wieku występowania pierwszej miesiączki wynosiła odpowiednio 12,33±1,46 lat wśród 38 dziewcząt z nadwagą, 12,48±0,92 lat w grupie 172 dziewcząt z prawidłową masą ciała i 13,90±0,13 lat wśród 33 dziewcząt z niedowagą (Durda-Maśny i wsp., 2019). Porównując dziewczęta zamieszkujące miejscowości wiejskie znajdujące się w okolicach miasta Poznania z dziewczętami mieszkającymi w mieście, można zauważyć, że w podobnym tempie rozwijały się dziewczęta z niedowagą, jednakże te z grupy z prawidłowa masa ciała i z nadwagą dojrzewały średnio wcześniej w mieście aniżeli na wsi.

Na uwagę zasługuje fakt występowania dużego zróżnicowania mediany wieku pierwszej miesiączki u badanych, w podziale na grupy względem występującej zmiany liczby ludności w trzydziestoletnim okresie obserwacji. W grupie dziewcząt, które zamieszkiwały tereny z zaobserwowanym zwiększeniem się populacji mediana wieku pierwszej miesiączki wyniosła 12,58 lat, i była niższa w stosunku do grupy z miejscowości, w których wzrost liczby ludności był niewielki lub nie ulegał zmianie - 13,65 lat. Gminy, w których nastąpiło zwiększenie liczby mieszkańców znajdowały się bliżej miasta Poznania od 19 do 37 km, natomiast miejscowości z drugiej grupy ulokowane były w odległości od 37 do 75 km od stolicy Wielkopolski. Można przypuszczać, że prawdopodobną przyczyną zaobserwowanego zróżnicowania w wieku występowania pierwszej miesiączki mogła być migracja ludności z miasta na wieś. W efekcie tego procesu teren wiejski upodabnia się do miejskiego a zjawisko to nosi nazwę semiurbanizacji wsi (Brańka, 2014). Potwierdzeniem tego założenia, może być informacja dotycząca liczby urodzeń w obserwowanych miejscowościach. Dane z rocznika statystycznego wskazywały, że tylko w jednej z pięciu gmin, w których nastąpił znaczny wzrost populacji, odnotowano zwiększanie się liczby urodzeń. W pozostałych dziewięciu gminach zmiany w szacunkowej liczbie urodzeń były nieznaczne w kolejnych trzech z nich, a w pozostałych sześciu prawie nie występowały.

Zmiany w poziomie wybranych zdolności motorycznych chłopców i dziewcząt z terenów wiejskich były zróżnicowane i nie wykazywały wspólnego kierunku. Badani

uzyskiwali niższe wyniki w teście szybkości (sprint 5 m) i gibkości (skłon tułowia), natomiast w teście mocy kończyn dolnych (wyskok dosiężny) i wydolności (sprawność układu krążenia) zmiany były zróżnicowane, wzrastały i malały w kolejnych dekadach. Należy zwrócić jednak uwagę na test zwinności (bieg po 8), którego wyniki poprawiały się we wszystkich 4 terminach obserwacji, a największy progres nastąpił pomiędzy latami 1986-1996. Te zmiany stanowią zaprzeczenie powszechnie panującej opinii, że poziom sprawności fizycznej dzieci i młodzieży obniża się. Można przypuszczać, że takie wyniki obserwacji świadczą raczej o zmianie struktury motoryczności, jako efekt adaptacji do zmieniających się warunków środowiskowych.

Duże zróżnicowane w obszarze poziomu zdolności motorycznych korespondowało ze zmianami dotyczącymi wysokości i masy ciała. Można przypuszczać, że zmiany wyników w poszczególnych testach są następstwem zwiększania się wartości BMI w badanej grupie. W badaniach ogólnokrajowych prowadzonych w latach 1979, 1989 i 1999 obserwowano obniżanie się lub stagnację wyników dla próby wydolnościowej (test Coopera), siły (dynamometr ręczny), czy mocy (skok w dal z miejsca) (Przewęda i Dobosz, 2007; Przewęda, 2009). Dane dla poszczególnych regionów wskazywały na obniżanie się uzyskiwanych wyników dla prób szybkości, wydolności, siły i zwinności pomiędzy latami 1965 a 1995 w grupie młodzieży z Górnego Śląska (Raczek, 1997). Obserwacje w regionie bydgoskim sugerowały poprawę siły, szybkości i zwinność w latach 1971-1981, jednak w latach 1981-1991 obniżyły się wszystkie wyniki w zakresie badanych przejawów zdolności motorycznych (Nowicki, 1996). W badaniach prowadzonych w grupie dzieci i młodzieży zamieszkujących wschodni region Polski obserwowano obniżenie poziomu poszczególnych zdolności motorycznych pomiędzy rokiem 1986 a 2006 (Saczuk, 2018) oraz 1986 a 2016 (Wilczewski i Wilczewski, 2018). Z kolei u młodzieży z miasta stołecznego Krakowa odnotowano obniżanie się wyników w teście siły mięśni zginaczy tułowia (tzw. „brzuszków”), skoku w dal z miejsca oraz skłonu tułowia w przód pomiędzy 1980 a 2000 rokiem. Dodatkowo zmiany wyników dla próby rzutu piłką lekarską i wyskoku dosiężnego przyjmowały różne kierunki w badaniach pomiędzy latami 1975-1980 a 2005-2010 (Mleczko, 2013). Zmiany poziomu zdolności motorycznych obserwowane w badaniach polskich, na ogół są zgodne z wynikami uzyskiwanymi w innych krajach (Tomkinson i wsp., 2007; Smpokos i wsp., 2012; Tomkinson i wsp., 2019; Ao i wsp., 2019; Dooley i wsp., 2020).

Porównania poziomu zdolności motorycznych pomiędzy grupami wyodrębnionymi na podstawie stanu odżywienia wskazały, że średnio niższe wyniki we wszystkich próbach, za

wyjątkiem gibkości, uzyskiwały osoby posiadające nadwagę lub otyłość, w porównaniu do osób z masą ciała w normie i z niedowagą. Należy jednak zauważyć, że wyniki uzyskiwane w pięciu testach sprawności były generalnie zbliżone we wszystkich grupach stanu odżywienia w poszczególnych seriach badań. Wyniki regresji wskazywały dużą zmienności w kolejnych terminach badań z uwzględnieniem grup wieku i wybranych zdolności motorycznych. Prawdopodobną przyczyną może być koncentracja wielkości próby w zakresie masy ciała w normie, z proporcjonalnie mniejszą liczbą dzieci i młodzieży w skrajnych zakresach rozkładu BMI.

Niemniej jednak relacje BMI z poszczególnymi zdolnościami motorycznymi w niniejszym badaniu były na ogół zgodne z tendencjami opisywanymi w literaturze. Przykładowo wyniki dla młodzieży wiejskiej 13-15 lat w latach 2006 i 2016 były zbliżone do analizy zależności między BMI a sprawnością fizyczną wśród młodzieży szkolnej w wieku 13-15 lat, zamieszkałej w powiecie konińskim, oddalonym o ok. 100 km od Poznania (Kwieciński i wsp., 2018). Pomimo, iż we wskazanym badaniu zastosowano odmienne testy sprawności fizycznej, zaobserwowano podobne kierunki związków, które wykazywały krzywoliniowe zależności pomiędzy BMI a: szybkością biegu, zwinnością i mocą u obu płci. W przypadku gibkości zależności były krzywoliniowe u chłopców i liniowe u dziewcząt w obu badaniach. Natomiast wyniki różniły się dla testów wydolności sercowo-naczyniowej, biegu na 1000 m (chłopcy) i 800 m (dziewczęta), w porównaniu ze step testem, zastosowanym w niniejszych obserwacjach.

W badaniach dotyczących dzieci tajwańskich wykazywano podobne relacje w próbie skoku w dal z miejsca, gdzie zależność w większości grup była krzywoliniowa, podobnie jak w teście wyskoku dosiężnego w niniejszych badaniach z 1996 roku (Huang i Malina, 2010). W przypadku oceny sprawności układu krążeniowo-oddechowego odnotowano krzywoliniowe zależności dla wyników biegu na 800 m (dziewczęta) i 1600 m (chłopcy) w grupie młodzieży tajwańskiej oraz dla step testu w grupie polskiej młodzieży w wieku 13-15 lat. Zależności liniowe w obu badaniach odnotowano dla biegu na 800 m u młodzieży tajwańskiej w wieku 9-10 lat i step testu u młodzieży polskiej w wieku 7-9 lat, natomiast wyniki były zróżnicowane dla młodzieży tajwańskiej w wieku 11-12 lat i polskiej w wieku 10-12 lat. Z drugiej strony wyniki w obu badaniach różniły się dla gibkości, gdzie odnotowano zależność krzywoliniową dla chłopców i dziewcząt z Tajwanu oraz zmienne zależności dla młodzieży polskiej.

Wyniki dzieci i młodzieży wiejskiej z 2016 roku można porównać z badaniami prowadzonymi w Brazylii w 2013 roku (Lopes i wsp., 2019). Obserwacje wykazały różne kierunki związków pomiędzy porównywanymi grupami. Wśród brazylijskiej młodzieży zależność między skokiem w dal a BMI była krzywoliniowa wśród młodzieży 10-11 i 12-13 letniej obu płci, jednak zaobserwowano, że w przedziale wieku 14-15 lat była krzywoliniowa u chłopców i liniowa wśród dziewcząt. Wśród młodzieży objętej niniejszymi badaniami zależność między wyskokiem dosiężnym a BMI była liniowa w wieku 10-12 lat, jednak krzywoliniowa w wieku 13-15 lat u obu płci. W przypadku wytrzymałości zależność między BMI a poziomem uzyskanym w Beep teście u brazylijskich dziewcząt w wieku 10-11, 12-13 i 14-15 lat była liniowa, natomiast między BMI a wynikiem step testu u polskiej młodzieży była krzywoliniowa u dziewcząt w wieku 10-12 lat i liniowa u dziewcząt w wieku 13-15 lat.

Trudność w znajdowaniu analogii czy też różnic w odniesieniu do rezultatów innych badań wynika z faktu stosowania różnych baterii testów podczas prowadzonych obserwacji. Jednak z drugiej strony, jeżeli służą one do oceny tego samego aspektu sprawności (np. ze względu na rodzaj wysiłku), można dokonywać pewnych porównań w odniesieniu do charakteru wykazanych związków.

Podsumowując wyniki uwzględniające zależności pomiędzy poszczególnymi testami sprawności a wskaźnikiem BMI różniły się w poszczególnych grupach wiekowych i terminach badań a jedną z prawdopodobnych przyczyn takiego układania się wyników może być koncentracja młodzieży w grupie o normalnym zakresie masy ciała i proporcjonalnie mniejszy jej udział w obu skrajnych jego zakresach – niedowaga i nadwaga. Analizy sugerują jednak na ogół dość spójne krzywoliniowe zależności między wynikami testów a BMI, występujące częściej u chłopców niż u dziewcząt.

Zmiany polityczno-gospodarcze w Polsce

Wszystkie wyżej opisane zmiany w budowie somatycznej, tempie dojrzewania i sprawności fizycznej należy rozpatrywać w kontekście głównych przemian politycznych, gospodarczych i społecznych, jakie następowały w Polsce w okresie objętym badaniami. Pierwszy termin przypadł na czas niezwykle burzliwy w historii Polski, związany ze strajkami robotników obejmującymi początek lat 80-tych, upadkiem rządu komunistycznego oraz pierwszymi wolnymi wyborami, które miały miejsce w 1991 roku.

Pomimo, iż szczegółowe dane dotyczące obserwowanych miejscowości nie są dostępne można założyć, że zmiany zachodzące w Polsce miały swoje odzwierciedlenie również w skali lokalnej, w poszczególnych częściach kraju, co mogło przyczynić się do ukierunkowanych zmian badanych cech i zdolności. Zmiany w sektorze gospodarczym, edukacyjnym i rolniczym oraz interakcje pomiędzy nimi są istotne dla dyskusji dotyczącej zmienności cech somatycznych, gdyż mają potencjalny wpływ na stan odżywienia i zdrowie społeczeństwa. Dodatkowo, przeobrażenia w sektorze rolniczym mają szczególne znaczenie dla wyjaśnienia uzyskanych wyników ze względu na obszar, w którym prowadzone były badania. Pomimo, iż po 1991 roku Polska gospodarka była stopniowo włączana do międzynarodowego i globalnego systemu gospodarczego, należy zauważyć, że w pierwszych dwóch terminach badań, a więc w 1986 i 1996, zmiany te nie były istotne lub nie mogły jeszcze wywołać realnego wpływu na rezultaty w obszarze poczynionych obserwacji (Urbanowska-Sojkin i Banaszyk, 2009).

Konieczność spłaty zadłużenia zagranicznego doprowadziła do deficytu towarów na rynku wewnętrznym, spadku realnych dochodów o połowę oraz inflacji, co znajdowało odzwierciedlenie w stanie populacji polskiej (Gomuła i wsp., 2015; Saczuk, 2018). Transformacja polityczna miała również duży wpływ na polskie rolnictwo. W 1990 r. Państwowe Gospodarstwa Rolne (PGR) zatrudniały prawie czterysta tysięcy osób, co ważne do 1988 roku ponad 50% środków przeznaczanych przez rząd na rolnictwo trafiało do PGR-ów, które pomimo to przynosiły olbrzymie straty. Cena jednostkowa produktów wytwarzanych przez rolników w latach 1990-1991 spadła o 63%, podczas gdy realne dochody gospodarstw rolnych zmniejszyły się o >40%, a płace pracowników spadły o około 37%. Wraz z przejściem na gospodarkę rynkową w 1991 r. zlikwidowano Państwowe Gospodarstwa Rolne (Kowalik, 2009).

W latach 80. w regionie obejmującym 10 obserwowanych miejscowości występował wysoki udział gospodarstw państwowych i spółdzielczych (Bański, 2010). Dwie gminy posiadały gospodarstwa państwowe (Pamiątkowo i Kwilcz), jedna - spółdzielcze (Wojnowice). Pozostałe gminy nie posiadały gospodarstw państwowych czy spółdzielczych, ale były położone w stosunkowo niewielkiej odległości od nich (4-10 km). Można przypuszczać, że część mieszkańców pracowała w PGR-ach i spółdzielczych gospodarstwach rolnych, w gminach były też małe gospodarstwa rodzinne. Jedna z gmin (Biedrusko) sąsiadowała z bazą wojskową (Baza danych Krajowego Ośrodka Wspierania Rolnictwa, 2019), która prawdopodobnie miała istotne znaczenie dla struktury zatrudnienia jej mieszkańców.

Państwowe i spółdzielcze gospodarstwa rolne wpływały również na życie społeczne w miejscowościach wiejskich i w wielu aspektach zapewniały zaspokojenie potrzeb pracowników i ich rodzin. Wraz z likwidacją PGR-ów w latach 90. i związanymi z tym zmianami polityczno-gospodarczymi, reorganizacji uległa również struktura i zakres usług, a nawet dostępność społeczności wiejskich do niektórych dóbr publicznych. Do najistotniejszych należy zaliczyć zmniejszenie liczby połączeń autobusowych i linii kolejowych oraz likwidację w latach 90. części małych wiejskich szkół podstawowych. Placówki biorące udział w niniejszym projekcie badawczym nie zostały objęte likwidacją. Z drugiej strony, pomimo iż rodzinne gospodarstwa rolne były generalnie bardziej produktywne w czasie reform, a wiele z nich aktywnie włączyło się w rozwijającą się gospodarkę rynkową, w wielu miejscowościach wiejskich wzrósł problem alkoholizmu, jako między innymi efekt bierności i poczucia bezradności, ponieważ ogólne warunki rolnicze uległy systematycznemu pogorszaniu (Górecki, 2015; Halamska, 2011).

Agencja Nieruchomości Rolnych w latach 1991-2004 prowadziła program dla byłych pracowników PGR. Liczba wniosków o zasiłek dla bezrobotnych, którzy wskazywali PGR-y jako ostatnie miejsce zatrudnienia wynosiła 100 tys. w 1991, a roku do roku 2004 liczba ta zmniejszyła się o połowę ponieważ bezrobotni otrzymywali oferty pracy. Dodatkowo na różne formy pomocy dla osób pracujących w PGR-ach w latach 1999-2004 wydano ok. 1,2 mld zł, w tym na stypendia edukacyjne. Byłym pracownikom PGR-ów zaoferowano również możliwość zakupu mieszkania po preferencyjnych stawkach (Zgliński, 2003).

Istotne znaczenie dla polskiego rolnictwa miało wejście do Unii Europejskiej w 2004 roku, kiedy to Polska została objęta Wspólną Polityką Rolną Unii Europejskiej. W jej ramach wprowadzono dopłaty bezpośrednie dla rolników do upraw oraz ułatwiono zakup maszyn rolniczych po obniżonych cenach. Z drugiej strony ograniczono liczbę małych gospodarstw rolnych produkujących żywność na własne potrzeby. Należy zwrócić również uwagę, że w okresie transformacji ustrojowej i gospodarczej zmniejszyła się liczba ludności wiejskiej. W 1960 r. ludność wiejska stanowiła 52% ludności Polski, w 1980 r. (tj. w okresie strajków i niepokojów politycznych) spadła do 41%, a w latach 1990 (38%) i 2016 (40%) utrzymywała się na stałym poziomie (Rocznik Statystyczny Rzeczpospolitej Polskiej, 2017).

Zmiany na obszarach wiejskich przylegających do dużych miast przyczyniły się do rozwoju stref podmiejskich, które mają coraz więcej cech wspólnych. Warto zwrócić uwagę na to, jak te i inne zmiany wpłynęły na warunki w konkretnych badanych miejscowościach,

a w konsekwencji na status rozwoju dzieci w wieku szkolnym w poszczególnych terminach badań obejmujących 30-letni przedział obserwacji.

Transformacja rynkowa prawdopodobnie przyczyniła się do poprawy, jakości edukacji na obszarach wiejskich, a liczba mieszkańców wsi z wyższym wykształceniem rosła w omawianym czasie. Na podstawie kwestionariuszy ankiet wypełnianych przez rodziców badanych dzieci i młodzieży w czterech dekadach można stwierdzić, że w 1986 roku większość rodziców posiadała jedynie wykształcenie podstawowe - średnio 77% zarówno ojców, jak i matek. W ankietach z lat 1996 i 2006 odsetek ojców z wykształceniem podstawowym zmniejszył się tylko nieznacznie, i było to odpowiednio 75% i 73%, natomiast odsetek matek z wykształceniem podstawowym zmniejszył się w większym stopniu - odpowiednio 67% i 57%. Z drugiej strony, w trzech pierwszych terminach badań odsetek matek z wykształceniem średnim stale wzrastał, odpowiednio 22%, 29% i 38%, podczas gdy analogiczny odsetek ojców zmienił się tylko nieznacznie, odpowiednio 19%, 19% i 23%. Odsetek rodziców obojga płci z wyższym wykształceniem w pierwszych trzech terminach badań wynosił 3% w 1986,5% w 1996 i 2006 roku. Struktura wykształcenia rodziców w 2016 r. uległa znacznej zmianie: odsetek ojców z wykształceniem podstawowym, średnim i wyższym wynosił odpowiednio 54%, 30% i 15%, podczas gdy odsetek matek wynosił odpowiednio 37%, 39% i 24% (Bartkowiak i wsp., 2021a)

Trudno jest jednak ocenić specyficzny wpływ zmian politycznych, ekonomicznych i społecznych w Polsce na zwyczaje żywieniowe i aktywność fizyczną, czyli dwa czynniki często wskazywane jako istotne w dyskusjach na temat zmian masy ciała, wskaźnika BMI oraz poziomu sprawności fizycznej (Przewęda, 2009; Gomuła i wsp., 2015; Gomuła i Kozieł, 2018). W związku ze wzrostem inflacji w latach 70. dostęp do produktów żywnościowych był ograniczony, a w połowie tej dekady (1976 r.) wprowadzono reglamentację żywności, najpierw cukru, następnie mięsa i jego przetworów, a w końcu masła, mąki zbożowej i ryżu. Rodziny otrzymywały „kartki” (talony) na te produkty spożywcze (Zawistowski, 2017), które towarzyszyły im do 1989. Reglamentowane produkty spożywcze były powszechnie uzupełniane przez wytwarzanie żywności na własne potrzeby na obszarach wiejskich (mleko, masło, jaja, mięsa - kury, kaczki, wieprzowina, wołowina) oraz przez wymianę barterową z sąsiadami (mięso za masło, jaja za mleko itp.), rozpowszechnioną zwłaszcza na terenach wiejskich. Po zmianach ustrojowych w latach 80-tych i stopniowym otwieraniu rynku, do Polski zaczęła trafiać żywność przetworzona, której spożywanie najprawdopodobniej doprowadziło do zwiększania się liczby osób z nadwagą i otyłością.

Kolejnym istotnym czynnikiem mogą być różnice w dziennych racjach pokarmowych młodzieży szkolnej. W Poznaniu w latach 1980-1990 szacunkowe średnie dzienne spożycie kalorii i poszczególnych składników pokarmowych wśród dziewcząt w wieku 13-15 lat w wynosiło odpowiednio 2278±628 kcal (61g białka, 102g tłuszczu, 280g węglowodanów) i 2144±728 kcal (59g białka, 87g tłuszczu, 282g węglowodanów). Odpowiednie wartości dla chłopców w wieku 13-15 lat wynosiły odpowiednio 2597±879 kcal (74g białka, 121g tłuszczu, 303g węglowodanów) i 2538±848 kcal (68g białka, 105g tłuszczu, 331g węglowodanów) (Przysławski i wsp., 1998).

Badania zwyczajów żywieniowych młodzieży w latach 1990-2000 wskazują na wzrost spożycia żywności przetworzonej oraz tej typu "fast food" (Augustyniak i Brzozowska, 2002). Na podstawie 24-godzinnego wywiadu żywieniowego stwierdzono, że młodzież wiejska spożywała mniej kalorii niż młodzież miejska, przy czym w obu grupach odnotowano wzrost energii pochodzącej z tłuszczu oraz spadek energii pochodzącej z węglowodanów i białek. Z kolei w dziennym spożyciu występowały niedobory składników mineralnych - wapnia, magnezu, miedzi, a wśród dziewcząt szczególnie żelaza. W ostatnim czasie odsetek polskiej młodzieży w wieku 13-15 lat spożywającej słodycze i słodkie napoje wzrósł ponad trzykrotnie w latach 2002-2018, odpowiednio z 18,1% do 69,9% i z 12,7% do 44,9%. W tym samym okresie odsetek osób spożywających codziennie warzywa zmieniły się nieznacznie z 36.6% do 34,2%, a spożywających codziennie owoce wzrósł z 23,1% do 38,2% (Augustyniak i Brzozowska, 2002; Woynarowska i Mazur, 2012; Mazur, 2015; Mazur i Małkowska-Szkutnik, 2018).

Powyższe trendy, choć interesujące, ograniczają się w dużej mierze do młodzieży i nie uwzględniają potencjalnych różnic między młodzieżą wiejską i miejską. Niemniej jednak spożycie słodyczy i słodkich napojów mogło przyczynić się do wzrostu rozpowszechnienia nadwagi i otyłości wśród dzieci i młodzieży w środowiskach wiejskich w latach 1996-2016.

Zmiany w sposobie żywienia w czasie mogą wpływać na wielkość masy ciała, która jest potencjalnie jednym z czynników warunkujących sprawność fizyczną i wiek pierwszej miesiączki, szczególnie w górnych skrajnych wartościach BMI. Ważną składową jest również aktywność fizyczna. Dane dotyczące poziomu aktywności fizycznej wśród polskich dzieci i młodzieży dostępne po 1990 roku wskazują, procentowe wartości 11-, 13- i 15-letnich chłopców zgłaszających podejmowanie intensywnej aktywności fizycznej (VPA) przez 4-7 dni w tygodniu w latach 1990-1998 wynosiły odpowiednio 54%, 51% i 42%, ale w 2018 roku

zmniejszyły się do odpowiednio 43%, 37% i 35%. Zaobserwowano, że odsetek chłopców niepodejmujących intensywnej aktywności 4-7 dni w tygodniu wzrósł w czasie. Odpowiednie dane dla dziewcząt w wieku 11 i 13 lat były niższe i w mniejszym stopniu ulegały obniżeniu, odpowiednio 38% i 31% w latach 90. oraz odpowiednio 36% i 27% w 2018 r. Odsetek dziewcząt w wieku 15 lat zgłaszających VPA 4-7 dni w tygodniu były z kolei niższy, ale stabilny w czasie - 20% w latach 90. i 22% w 2018 roku (Woynarowska i Mazur, 2012; Mazur, 2015; Mazur i Małkowska-Szkutnik, 2018).

Przy zmodyfikowanym wskaźniku umiarkowanej aktywności fizycznej (MVPA), który obejmował obowiązkowe wychowanie fizyczne w szkołach (4 godziny/tydzień od 2003 roku), odsetek polskich chłopców deklarujących MVPA przez siedem dni w tygodniu, w pięciu badaniach obejmujących lata 2002-2018 wahały się od 24% do 34% w wieku 11 lat, od 16% do 29% w wieku 13 lat i od 16% do 25% w wieku 15 lat. Odpowiedni odsetek polskich dziewcząt zgłaszających MVPA przez siedem dni w tygodniu w tym samym przedziale czasowym wynosiły od 18% do 27% w wieku 11 lat, od 12% do 18% w wieku 13 lat i od 8% do 11% w wieku 15 lat. Spadkom aktywności fizycznej towarzyszył wzrost zachowań sedenteryjnych. Przy uwzględnieniu niewielkich różnic w badaniach z lat 2000 i 2018, ponad 50% młodzieży w wieku 11-15 lat spędzało od 2 do 3 godzin dziennie na oglądaniu telewizji/filmów w dni szkolne, a jeszcze więcej w weekendy. Odsetek młodzieży spędzającej od 2 do 3 godzin dziennie przy grach komputerowych był stosunkowo niski w dni szkolne, zwłaszcza wśród dziewcząt, ale 46% do 58% chłopców w wieku 13-15 lat deklarowało ponad 4-godzinne granie w gry komputerowe w weekendy, przy czym różnice między badaniami były niewielkie (Woynarowska i Mazur, 2012; Mazur, 2015; Mazur i Małkowska-Szkutnik, 2018).

W niezależnym badaniu z 2011 r., ponad 50% polskiej młodzieży gimnazjalnej i licealnej spędzało 3 godziny i więcej dziennie na oglądaniu telewizji lub korzystaniu z komputera. Poprzez analogię można stwierdzić na podstawie tych danych, że zdecydowana większość polskiej młodzieży w wieku 11-15 lat nie była aktywna w sposób umiarkowany, na co dzień w latach 2002-2018. Co istotne, wysokie poziomy VPA i MVPA wiążą się z niższym ryzykiem otyłości niezależnie od zachowań sedenteryjnych (Katzmarzyk i wsp., 2015).

W obliczu ilości zmiennych nie łatwo dokonać oceny poziomu zdolności motorycznych młodzieży w kontekście przemian gospodarczych i społecznych związanych z transformacją

ustrojową w latach 80. i następnych. Można jednak potwierdzić, że zmiany te miały wpływ na istotne dla jej poziomu elementy systemu edukacji. Wychowanie fizyczne, które było obowiązkowe w wymiarze 2 godzin tygodniowo, zostało zwiększone do 3 godzin tygodniowo w 1997 roku i do 4 godzin tygodniowo w 2002 roku. Z tego ostatniego wymogu 3 godziny tygodniowo były obowiązkowe, podczas gdy czwarta godzina była opcjonalna i zależała od dostępności lokali i możliwości organizacji zajęć poza szkołą, na przykład: na pływalni, biegania w lesie, jazdy na nartach i tym podobnych (Janowski, 2017; Woynarowska, 2008). System oceniania z wychowania fizycznego został poszerzony o podstawowe zdolności motoryczne oraz aktywność fizyczną. Z czasem ocena umiejętności ruchowych i poziomu poszczególnych zdolności motorycznych była coraz częściej umieszczana w kontekście prezentowanego poziomu sprawności fizycznej, a jej celem było przygotowanie młodzieży szkolnej do podejmowania aktywności fizycznej przez całe życie (RMEN, 2017).

Wdrażanie zmian w wychowaniu fizycznym było jednak bardzo zróżnicowane, pomimo szczegółowych programów i systemów ewaluacji. Na przykład w latach 2007-2009 w ponad połowie szkół w Polsce program tego przedmiotu nie został dostosowany do przepisów, a nowa podstawa programowa na lata 2009-2010 nie została wdrożona w 20% placówek. Co istotne dla niniejszej dyskusji, w trakcie krajowej kontroli odnotowano, że dwie trzecie szkół nie monitorowało postępów uczniów w zakresie wychowania fizycznego, w tym nie wykonywało testów sprawności fizycznej. Oszacowano również, że 20% do 40% młodzieży szkolnej uczestniczyło w mniejszej liczbie lekcji wychowania fizycznego i zajęć ruchowych niż wymaga tego prawo, a tendencja ta wzrastała wraz z wiekiem uczniów (Woynarowska i wsp., 2015).

W związku z przemianami gospodarczymi i politycznymi w Polsce oraz związanymi z nimi zmianami społecznymi, zawodowymi i edukacyjnymi, polska rodzina i warunki życia uległy zmianie, szczególnie w latach 2006-2016. Być może najbardziej znaczące było zmniejszenie liczby rodzin wielopokoleniowych oraz liczby dzieci w rodzinie. Trendy te prawdopodobnie odzwierciedlają rezultaty wyborów młodych ludzi, którzy coraz częściej inwestowali czas w edukację, starając się osiągnąć poziom wykształcenia zapewniający stabilność ekonomiczną, w tym zwiększanie się liczby pracujących matek. Zmiany te niewątpliwie wpłynęły na obowiązki związane z opieką nad dziećmi i ich zajęciami pozaszkolnymi (Bieńkowska i Kitlińska-Król, 2017). Dokonana analiza nie wyczerpała całościowo tematu a uzyskane wyniki wskazują na niezmienną zasadność podejmowanych badań w tym obszarze. Co więcej pojawiły się nowe i dotychczas nie poruszane

w piśmiennictwie wątki, które służyć będą kontynuacji i rozszerzaniu przedstawionych obszarów obserwacji w niniejszej dysertacji.

Podsumowując, można założyć, że niepokoje polityczne i związana z nimi niepewność ekonomiczna i społeczna w Polsce w okresie między badaniami mogły wpłynąć na warunki życia w gminach, a w szczególności w rodzinach, co z kolei mogło przyczynić się częściowo do zmian w zakresie wysokości i masy ciała dzieci oraz młodzieży, wieku wystąpienia pierwszej miesiączki oraz do zwiększonego rozpowszechnienia nadwagi i otyłości w badaniach z 2006 i 2016 roku. Prawdziwe wydawać się może również stwierdzenie, że warunki życia dzieci w badaniach z 2006 i 2016 r. uległy poprawie w porównaniu do realiów bytowych dzieci we wcześniejszych badaniach, czego dowodem może być obniżanie się wieku pierwszej miesiączki. Zmiany sprawności fizycznej były generalnie zgodne ze obserwowanym regresem poziomu aktywności fizycznej i wzrostem częstości biernych ruchowo form spędzania czasu wolnego polskiej młodzieży od lat 90. XX wieku. Wpływ na obserwowane parametry mogą mieć również zmiany w sposobie odżywiania związane ze zwiększoną konsumpcją żywności wysokoprzetworzonej – tzw. „*fast food*" i słodkich napojów oraz coraz bardziej sedenteryjnym stylem życia. Wyjątkowość niniejszego projektu badawczego polega na tym, że młodzież szkolna badana była czterokrotnie w dokładnie tych samych 10 miejscowościach.

6. Ograniczenia pracy

Przeprowadzone badania nie są pozbawione ograniczeń. Jednym z nich był brak wyznaczenia wskaźnika dojrzałości biologicznej dla obu płci, co mogłoby wnieść interesujące tło do analiz. Kolejnymi było pominięcie zbierania informacji o deklarowanej aktywności fizycznej i zwyczajach żywieniowych w obserwowanych miejscowościach wiejskich w pierwszych trzech terminach obserwacji. Biorąc pod uwagę brak takich informacji trudno jest oceniać relacje pomiędzy wynikami pomiarów antropometrycznych i sprawnościowych a zmianami środowiskowymi.

7. Wnioski

Na podstawie przeprowadzonych analiz opracowano następujące wnioski:

W1. W trzydziestoletnim okresie obserwacji dzieci i młodzieży z regionu Wielkopolski stwierdzono występowanie zmian w wysokości i masie ciała oraz wskaźniku wagowo-wzrostowym (BMI). Wielkości cech somatycznych zwiększyły się istotnie statystycznie pomiędzy skrajnymi terminami obserwacji. O ile jednak w przypadku wysokości ciała zmiany mają charakter progresywny, mogący świadczyć o poprawie warunków życia, o tyle zwiększanie się masy ciała i wskaźnika BMI, jest tendencją negatywną mogącą prowadzić w późniejszych latach do występowania wielu chorób cywilizacyjnych w obserwowanej populacji.

W2. Analiza wyników wskazała na występowanie relacji pomiędzy grupami stanu odżywienia a wiekiem występowania pierwszej miesiączki. Stwierdzono, że w obserwowanej populacji najwcześniej dojrzewały dziewczęta z nadwagą, następnie z prawidłową masą ciała, a najpóźniej z grupy z niedowagą.
Dodatkowo zaobserwowano zróżnicowanie wieku występowania pierwszej miesiączki w podziale uwzgledniającym zmiany wielkości populacji w trzydziestoletnim okresie badań. W grupie dziewcząt zamieszkujących tereny z zaobserwowanym przyrostem liczby ludności wiek występowania menarche był niższy o około rok w porównaniu do grupy dziewcząt z miejscowości gdzie przyrost nie występował lub był niewielki.

W3. W trzydziestoletnim okresie obserwacji dzieci i młodzieży z regionu Wielkopolski stwierdzono występowanie zmian w wielkości uzyskiwanych wyników w testach sprawności określających poziom omawianych zdolności motorycznych. Wyniki nie wykazywały wspólnego kierunku zmian pomiędzy kolejnymi terminami badań, a systematyczną poprawą stwierdzoną wyłącznie w teście zwinności. Wyniki obserwacji mogą świadczyć o przystosowaniu struktury motoryczności, jako efekt adaptacji, do zmieniających się warunków środowiskowych.

W4. W trzydziestoletnim okresie obserwacji dzieci i młodzieży z regionu Wielkopolski stwierdzono w większości przypadków krzywoliniową zależność pomiędzy BMI a poszczególnymi zdolnościami motorycznymi. Wyższe wyniki uzyskiwały dzieci i młodzież z BMI w średnim zakresie rozkładu, podczas gdy wyniki badanych

znajdujących się w dolnym i górnym zakresie rozkładu były niższe. Wyniki różniły się w zależności od grup wiekowych, terminów badań i płci. Prawdopodobną przyczyną takiego przebiegu zależności mogła być koncentracja liczby dzieci i młodzieży w grupie o masie ciała w normie i proporcjonalnie mniejszy odsetek w obu skrajnych zakresach – niedowaga i nadwaga.

W5. Na podstawie szczegółowej analizy wyników stwierdzono, że występują specyficzne okresy wzmożonego rozwoju zarówno w przypadku cech somatycznych jak i zdolności motorycznych u obu płci. Ich przebieg nie jest liniowy oraz różnił się w ciągu trzech dziesięcioleci, w poszczególnych grupach wieku oraz pomiędzy grupami dziewcząt i chłopców. Nie zaobserwowano jednego kierunku zmian w okresach wzmożonego rozwoju w kontekście przemian społeczno-gospodarczych.

II. DISSERTATION SUMMARY

The doctoral dissertation is based on series of surveys entitled: ***Changes in the somatic and motor development of children from the Wielkopolska region in subsequent decades from 1986 to 2016 in the context of selected environmental changes***.

It consists of five articles in peer-reviewed journals based on surveys in 1986, 1996, 2006 and 2016. Funding for the 1986, 1996, and 2006 surveys was provided by the Scientific Research Committee (Komitet Badań Naukowych - Badnia Własne). The last survey in 2016 was funded by the project Development of Young Researchers, implemented at the Poznań University of Physical Education.

The dissertation includes the following articles:

1. ***Secular change in height and weight of rural school children and youth in west-central Poland: 1986 to 2016.*** American Journal of Human Biology: The Official Journal of the Human Biology Council, 33(2), e23461. https://doi.org /10.1002/ajhb.23461 Impact Factor: 1.937, punktacja MEiN: 70.000

2. ***Weight status of rural school youth in Poland: Secular change 1986-2016.*** Anthropologischer Anzeiger; Bericht Uber Die Biologisch-Anthropologische Literatur, 79(1), 43–56. https://doi.org/10.1127/anthranz/2021/1500 Impact Factor: 0.877, punktacja MEiN: 70.000

3. ***Age at menarche among rural school youth in west-central Poland: variation with weight status and population growth*.** Anthropological Review, 2021 84(1), 51-58. https://doi.org/10.2478/anre-2021-0006 punktacja MEiN: 70.000

4. ***Physical Fitness of Rural Polish School Youth: Trends between 1986 and 2016*** Journal of Physical Activity and Health, 2021 28;18(7):789-800. https://doi.org/ 10.1123/jpah.2020-0712. Impact Factor: 2.592, punktacja MEiN: 70.000

5. ***Relationship between BMI and physical fitness of Polish School Youth: Trends between 1986 and 2016*** Acta Kinesiologica 2021, 15 (2):134-143 https://doi.org/10.51371/issn.1840-2976.2021.15.2.18 punktacja MEiN: 140.000

The bibliometric data of the article series are: IF index 5,406 and 420 MEiN* points.

* The points established by the Ministry of Education and Science in Poland.

The structure of the dissertation includes the:

1. **Introduction** presents a review of the literature on the current state of knowledge with particular emphasis on the directions of changes in somatic and motor characteristics and their possible causes, a summary of the rationale for systematically addressing.

2. **Aim** this section presents specific objectives and research question.

3. **Material and methods**, the subsequent chapters describe the research materials and methods that are the basis for the overall study and are the basis for each of the respective papers.

4. **Results**, this section includes five subsections, each addressing the five published papers and highlighting the key observations related to the individual research objectives and questions. Each subsection ends with a brief summary.

5. **Discussion,** this section provides an overview of the results and considers factors that may have influenced the obtained results

6. **Limitations** in this chapter, the author points out the limitations of the paper that can be added to the observations made in the future.

7. **Conclusions** in this chapter overall conclusions of the dissertation are presented.

1. Introduction

The environment undergoes constant transformations that affect living organisms. In order to maintain internal balance, it is necessary for adaptive processes to occur, which result, among other things, in changes in somatic structure and the level of physical fitness.

Changes in the human genotype may occur within the range of a certain norm called the reaction norm, the level of development of which will depend on in addition to genetic determinants, as well as the influence of particular environmental factors. There are three main groups of factors determining the dynamics of human biological development in ontogenesis. These factors include: endogenous genetic - development determinants, endogenous paragenetic - development stimulators and exogenous - development modifiers. In the last group, there is a subgroup of biogeographic natural modifiers, which include fauna and flora, composition: water, air, soil, mineral resources, landforms and climate, and a subgroup of socio-cultural modifiers such as social origin, nature and size of the environment, level of education, amount of income, traditions and social customs. The fourth factor distinguished, lying on the border between genetic and environmental conditions, is lifestyle (Cieślik et al., 1985).

Examples of the above-described factors may also include political and economic changes occurring in individual countries, geographical location, air pollution or level of urbanization of the region. They can affect the occurrence of slow long-term, directional intergenerational changes called secular trends within the parameters characterizing the level of biological and morphological development of the population.

Observations of secular trends describing changes in body size of children, adolescents and adults have a long tradition both globally, describing changes between continents, and locally, showing changes in a given country or region (Malina, 1979, 2004; Roche, 1979; Tanner, 1962, 1981, 1992). Similar observations have also been made in Poland for over 100 years (Bielicki and Szklarska, 1999; Jankowiak, 1962; Jasicki, 1938; Łopuszańska-Dawid et al., 2020; Trześniowski, 1990). Published data consistently show an urban-rural gradient in achievement size over time (Hulanicka et al, 1990; Łaska Mierzejewska et al, 2016; Nowak, 2012; Przewęda and Dobosz, 2003), but it is important to note that differences between urban and rural children and adolescents have narrowed over the past 40 years. Changes in the structure of the Polish countryside, such as the liquidation of the State Agricultural Farms

(PGR) after 1992, the possibility of benefiting from European Union programs such as the Rural Development Program from 2007, and the development of digitization affecting the process of disseminating knowledge (Gomuła et al., 2015; Łaska-Mierzejewska et al., 2016; Łaska-Mierzejewska and Olszewska, 2003, 2009; Janowski, 2017; Saczuk, 2018).

Recently observed height and weight gains in rural children and adolescents in Poland were consistent with those found among the general population and those from large cities. For example, in surveys conducted at decade intervals from 1986 to 2016, a significant increase in height and body mass of school children and adolescents living in towns and villages in several provinces in eastern Poland were reported in the first two terms. Subsequent observations showed a continuation of the increasing trend; however, the changes were not statistically significant (Saczuk, 2018). Among school-aged children aged 7 to 15 years from seven rural villages in the copper mining district of Lower Silesia, height and weight increased significantly between 2000-2001 and 2010-2011, although weight increased proportionally more than height (Ignasiak et al., 2016).

The magnitudes of changes in height and weight affect changes in the Body Mass Index (BMI, kg/m^2). In Poland, as in most highly developed countries, for years there has been an unfavorable trend associated with an increase in the number of overweight and obese children, resulting in serious adverse health effects. Additionally, the interventions that have been undertaken are not having the intended effect and the rate of increase in overweight and obesity has influenced it to be referred to as an epidemic (Levin, 2000; WHO, 2000).

Changes in lifestyle, eating habits, and decreases in time spent on daily physical activity and a shift to sedentary lifestyles are often cited as primary factors associated with the increasing prevalence of overweight and obesity among children and adolescents (Lobstein et al., 2004; Hu, 2011). Although current discussions primarily focus on overweight and obesity, there is also a problem with too low a body weight for height (low BMI), referred to as underweight or thinness. It occurs at high levels in certain areas of the world or in certain social groups (de Onis et al., 2007; de Onis and Lobstein, 2010).

Secular trends in the variation of BMI and/or prevalence of overweight and obesity among children and adolescents in Poland similarly to observations on changes in height and weight have been studied in nationwide samples (Gomuła et al., 2015), but also in regional samples (Chrzanowska et al., 2007; Mazur et al., 2014; Saczuk and Wasiluk, 2014; Perenc

et al., 2016). They mostly covered the years 1966-2014, although the interval between each survey varied. In contrast, only one addressed the problem of excessive thinness and looked at changes between 1986 and 2006 (Saczuk and Wasiluk, 2014)

Changes in height, weight, and BMI can affect the age at menarche, which is a widely accepted indicator of biological maturity in girls. Globally, the observed trend of decreasing age of first menstruation was generally associated with improved living conditions, health status, nutritional conditions, and socioeconomic development (Nieczuja-Dwojacka et al., 2018). It has also been suggested that the average age of first menstruation in some populations may be approaching the "genetic limit" given the reduced associations with socioeconomic and environmental factors (Golding et al., 2001).

Corresponding data for Poland from the late 19th century indicate a median age of menarche of 15.2 years (Kowalska, 1966). More recent analyses of national survey results have noted intergenerational declines in the age of first menstruation to 12.9 years and the persistence of urban-rural contrasts between 1966 and 2012 (Gomula and Koziel, 2018). In summary, it was noted that the median age of menarche for girls residing in rural areas was consistently later on average than for urban girls. In contrast, daughters of rural non-farm families reached menarche earlier than those from farm families (Łaska-Mierzejewska et al., 2016).

It is assumed that a certain level of somatic traits constitutes a predisposition for obtaining a high level of physical fitness. Analyzing changes in the level of physical performance and fitness, as an effect of genetic predisposition, and undertaken physical activity, in relation to a healthy lifestyle, of schoolchildren has a long tradition, (Malina, 1978; Malina et al., 2004), which has increased more recently in the era of systematic reviews (Dooley et al., 2020; Tomkinson and Olds, 2017). This tradition continues in many countries, although time intervals and fitness items considered vary (Tomkinson and Olds, 2017; Fraser et al., 2015).

Given current concerns for the health-related fitness of youth and potential associations with health status in adulthood (Lamb et al., 1988), cardiovascular endurance and flexibility are emphasized. Performance-related fitness as apparent in tests of speed, agility, and power are central to physical activity in its many forms among youth. Moreover, a physically active lifestyle during youth that includes sufficient levels of moderate and vigorous physical activity is generally accepted as a health promotion and disease prevention strategy (Strong et al., 2005).

The fitness and activity of youth also have the potential to impact quality of life that may persist into adulthood.

Surveys of the physical fitness in national samples of Polish youth 7–19 years date back to 1932 (Mydlarski, 1934), while the fitness of youth in the city of Cracow was first surveyed in 1938 (Bocheńska, 1972). Both surveys were done during the interval between 1918 when Poland regained its independence, and 1939, when World War II began with the invasion of Poland by Germany. Subsequent national surveys of youth fitness in 1951, 1966, and 197915 (Trześniowski, 1961, 1990), spanned the interval of postwar communist control, while comparisons of prewar and postwar fitness levels in several tests indicated negligible changes between 1932 and 1951 in national samples and inconsistent changes between 1938 and 1962 in Cracow boys (Bocheńska, 1972).

The early surveys focused largely on speed, strength, and power, while more recent surveys shifted to international fitness batteries, for example, the International Committee for the Standardization of Physical Fitness Test and EUROFIT test battery (Larson, 1974), in addition to the Cooper test (Cooper, 1968), as a measure of cardiovascular endurance. In doing so, the fitness of Polish youth has been placed in the context of the European and international communities. Overall, performances of Polish youth on fitness tests (speed, power, and strength) were variable across surveys before and after World War II. Allowing for the different tests, fitness levels of Polish youth generally improved in surveys through 1981, but more recently changes in fitness have been variable, and, in many cases declined. Urban–rural contrasts were apparent in several fitness tests in the 1999 national survey (Przewęda and Dobosz., 2007).

Given the preceding as background, it was decided that there is a need for systematic analysis of secular changes in somatic development and motor performance, and their relationships in school children and adolescents. The present study is unique in that the school children and adolescents from the same ten communities surveyed in 1986, 1996, 2006 and 2016 were the focus of study.

2. Purpose of the study

The aim of the study was to determine the magnitude and direction of changes in the development of selected somatic characteristics and motor abilities of children and adolescents from rural areas of the Wielkopolska region and to search for their probable environmental causes in socio-economic terms.

Research Questions:

1. Are there any changes in the level of selected somatic parameters in children from Wielkopolska region and if so, what is their direction and magnitude? [publication 1and 2]

2. Is there a relationship between the age at menarche and weight status groups and changes in population size among girls from the observed region of Wielkopolska, and if so, what is the relationship? [publication 3]

3. Are there changes in the level of physical fitness of children from the Wielkopolska region and if so, what is their direction magnitude? [publication 4]

4. Is there a relationship between BMI and physical fitness in a group of observed children from the Wielkopolska region, and if so, what is its linear or curvilinear? [publication 5]

5. Are there periods of increased development of somatic traits and motor skills in successive decades of study among observed children and do they apply to the same age ranges in the context of socioeconomic change? [publication 1, 2 and 4]

3. Methods and methods

The surveys were conducted in four series at decade intervals. The first took place in 1986 (Strzelczyk, 1995), the second in 1996 (Janowski, 2001, Karpowicz, 2001), the third in 2006 (Janowski, 2017), and the fourth in 2016 (Bartkowiak et al., 2021a; 2021b, 2021c, 2021d, 2022).

The survey was conducted in 10 rural communities in Wielkopolska Region: Kołaczkowo, Kłecko, Nekla, Pamiątkowo, Biedrusko, Strykowo, Granowo, Wojnowice, Kwilcz and Obrzycko. The selection of particular schools was made during the first series of surveys in 1986 and the basic criterion was the technical and organizational capacity to carry out the surveys, e.g. the presence of a gymnasium and even distribution of the selected schools around the center of the voivodeship (Strzelczyk 1995). Schools were selected in consultation with the School Superintendent's Office in Poznań. Subsequent series of surveys were continued in exactly the same locations.

3.1 Samples

Children and youth in age 7-15 comprising the samples were enrolled in elementary schools (1986, 1996, 2006, 2016) and gymnasiums (2006, 2016) in each community. In 1986, 1417 boys and 1326 girls were examined, in 1996: 979 boys and 947 girls in 2006: 871 boys and 843 girls and in 2016: 1189 boys and 1105 girls. A total of 4531 boys and 4332 girls were examined (n = 8863).

Children were classified into single year chronological age (CA) groups with the whole year as the mid-point of the interval, that is, 7 years = 6.50 to 7.49, 8 years = 7.50 to 8.49, ...through ..., 15 years = 14.50 to 15.49 years.

Given variable numbers across surveys, the samples in each survey were combined into three age groups for more detailed analyses of secular change: (a) 7 to 9 years - middle childhood in both sexes; (b) 10 to 12 years - transition into puberty and mid-puberty (most girls) and transition into puberty (most boys); and (c) 13 to 15 years - late adolescence (most girls), interval of the growth spurt (most boys).

The survey excluded students whose parents didn’t agree to participate in the measurements and those who had long-term medical exemptions from compulsory physical

education classes. Moreover, the results of children attending special classes that were part of the studied departments were not included in the analyses.

3.2 Procedures

The surveys were carried during physical education lessons, with the cooperation of the school director and physical education teachers. Measurements were taken in the gymnasium of each school in the morning, by the research team, employees of the Department of Theory and Department of Anthropology and Biometry of the University of Physical Education in Poznan. The adopted standardized procedures were continued on subsequent dates to maintain a logical continuity of comparisons and the ability to analyze changes over a long observation period.

First, the entire class was assembled to check attendance and to determine the alphabetical order of those assembled, so that when the tests were administered, students approached subsequent trials in the same order. Then the aim of the survey was presented to the children and all activities that will be performed to implement the principle of conscious and active participation were presented and described.

In the next stage, selected somatic parameters were measured, followed by a standardized warm-up and the performance of individual physical fitness tests according to the adopted methodology and level of difficulty. After the measurements were completed, the participants went to the classroom, where they filled out the survey questionnaire in the presence of a trained interviewer.

3.2.1 Anthropometry

In order to characterize the level of somatic development, a wide range of anthropometric measurements were used, which were performed according to the current principles in anthropometry (Martin and Saller, 1975). Using an anthropometer (GPM, Switzerland), body height was measured and the result was reported with an accuracy of 0.1 cm. Body weight was measured to the nearest 0.1 kg using a medical scale (Lublin Scale Factory, Poland) in 1986 and using electronic scales in subsequent studies (Wielkopolska Scales, Poland, 1996 and 2006 studies; Tanita, Japan, 2016 study).

Subsequently, on the basis of the height and weight results, the Body Mass Index The BMI was calculated (kg/m^2) and used to classify the weight status of each student as severely,

moderately or mildly thin, normal, OWT or OB using age- and sex-specific IOTF cut-offs (Coleet al., 2000; Cole et al., 2007).

3.2.2 Fitness tests

In order to determine the level of selected elements of physical fitness, 5 fitness tests were performed: a 5-meter run, stand and reach test, vertical jump, a modified 5-minute Harvard step-test, a figure-eight run.

Speed— 5-m Run (in Meters per Second).

The student was standing at a line 0.5 m from the starting line. At the start command, he/she ran as fast as possible crossing the starting and finish lines and through markers placed 1 m beyond the latter. Time elapsed from crossing the starting and finishing lines was measured (0.001 s) with laser photocells located 0.5 m above ground on each line (PFL-20 Kabid-Zopan, Poland, 1986, 1996, 2006; Witty, Microgate, Italy, 2016). Two trials were given; the better time was retained. Distance covered per second (in meter per second) was calculated. (Wachowski et al., 1987). The obtained result was used to determine the velocity according to the formula:

$$V=s/t \text{ [m/s]}$$

where: V - velocity [m/s] s - distance [m] t - time [s].

Explosive Power Jumping ability—Vertical Jump (in Centimeters).

Standing erect with his/her side to the centimeter scale, the student extended his/her arm upward along the scale; the highest point (standing reach height) was recorded (nearest centimeter). Then from a half squat position, the student was instructed to jump as high as possible using both arms and legs to assist in projecting the body upward. The highest point of the jump indicated by the reach of the fingers was recorded (in centimeters). The difference between standing reach height and jump height was the score. Three trials were given; the best jump was retained (Wachowski et al., 1987).

Flexibility—Stand and Reach with a Forward Bend (in Centimeters).

Without shoes, the student was standing with feet together on a box (height = 32 cm, length = 35 cm, width = 45 cm). The measurement scale was 50 cm at the standing surface and values increased downward. The student was instructed to raise their arms, make the deepest

forward bend possible, and hold this position for 1 or 2 seconds. The score was recorded (nearest centimeter) as the distance reached. The forward bend was performed twice; the better result was retained (Wachowski et al., 1987).

Agility—Figure 8 Run (in Seconds).

Standing at the starting line midway between 2 poles (120 cm) 5 m apart, the student was instructed to run the figure 8 pattern as fast as possible. The pattern was run 3 times, with the first turn to the right. The time to cover the 3 laps was measured with a stopwatch (0.01 s, 1986, CAENAHOB, C.C.C.P./SLAVA, Russia, 1986; Casio HS-80TW Lap Stop-watch, Japan, 1996, 2006, 2016). Two trials were given; the better results were retained (Fleishman 1964; Pawlak and Sarna 1982).

Cardiovascular Fitness—Modified Harvard Step Test.

The student stepped up and down a box 30.0 cm in height at a metronome pace of 30 full steps (up/down) per minute for 5 minutes (300 s). After 5 minutes and resting for 1 minute, heart rate was recorded for 60 seconds using an electronic sensor on the second finger in 1986 and 1996 (N-327-5 analog unit) and with an electronic sensor in the earlobe in 2006 and 2016 (AND C812 analog unit with Tester software (Poznań Technical University).

A STI was calculated:

$$\text{STI} = 100 \times (\text{working time in seconds})/5.5 \times p\ ,$$

where p = 60 second pulse rate measured between first and second minute after completion of the exercise; 5.5 = constant.

As a guide, a step test index >60 = very high, >50.0 and <60 =high; >40.0 and <50 = average; >30.0 and <40 = low; <30.0 = significantly impaired (Gruszczyński et al., 1974; Mazur et al., 1975).

3.3 Environmental factors

In order to collected information on the overall environment of the study, questionnaires were used to collect information parental education and occupation, school environment and the children. The questionnaire developed by Strzelczyk (1995) for the first survey in 1986 was also used in the subsequent surveys. The survey questionnaires met the accuracy and reliability

requirements. Menarcheal status was obtained via interview. Each girl was individually interviewed by a female member of the research staff as to whether menarche had occurred (yes) or had not yet occurred (no).

The initial survey was approved by the provincial Board of Education and Development and educational authorities of each community following regulations that were in effect at the time. The subsequent surveys were approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (KB 907/16 for 2016) and educational authorities of each community.

3.4 Statistical analysis

Basic statistical analyses were performed: normality in frequentist statistics was assessed using the Shapiro-Wilk test, arithmetic mean [M], standard deviation [SD], standard error [SE] and median [ME] were calculated for individual calendar age groups for boys and girls respectively in each series of the study. From these, baseline characteristics were developed and graphs were created showing the direction of change over time.

Then, comparisons across the four surveys in each of the three age groups were then addressed with sex-specific analyses of covariance (ANCOVAs) with age and age^2 as covariates. Age and age^2 adjust for potential linear and nonlinear effects of age distributions, respectively. Pairwise post hoc comparisons between specific surveys, adjusted for multiple comparisons (Bonferroni), were evaluated. The post hoc comparisons indicate the significance of differences across the 30 year interval and between specific surveys. In addition, in article 5, in order to observe possible relationships between physical fitness tests and BMI were used sex-specific regressions by survey using linear and nonlinear quadratic models. The test was the dependent variable; the BMI was the independent variable in the linear model, while the BMI and BMI^2 were independent variables in the quadratic model.

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) for Windows (version 22.0, IBM SPSS, Chicago, IL).

4. Results

The main results of the conducted research as reported in the related publications, are presented below. This section includes five subsections, each addressing the five published All of the information presented below in the tables or figures in each publication refers to the original articles.

Publication 1.

Secular change in height and weight of rural school children and youth in west-central Poland: 1986 to 2016. American Journal of Human Biology, 2021 ;33(2):e23461

The purpose of this study was to compare changes in height and weight of children aged 7-15 years on four survey dates conducted at decade intervals from 1986 to 2016.

In this study, analyses were performed with three divisional criteria:

a) analysis of subjects by observation period considering single age groups (7, 8, 9, ..., 15 years);
b) analysis by three age groups (7-9, 10-12, 13-15 years)
c) analysis of changes between decades (1986-2016, 1986-1996, 1996-2006, 2006-2016).

Re a) Analysis of the data on body height by single age group, showed that the highest were children and adolescents in the last series of studies (2016), and this trend was observed in both sexes. Among boys (Figure 2A), heights at 7 and 8 years do no differ between 1986 and 1996 and between 2006 and 2016, In the subsequent age groups of boys, a systematic, almost linear increase in body height was observed in the following decades (Figure 2A). Among girls, the results didn't follow such a regular pattern as in the boys' group. heights in 1996 and 2006 do not consistently differ throughout the age range, allowing for the sample of 7 year old girls in 2006 which was significantly older than samples in the other surveys. Girls in the last decade were on average taller than those of girls in the other three surveys (Figure 3A).

Trends in body weight suggest a secular increase across the four surveys of boys. The largest differences between age groups were between the extreme terms (Figure 2B). Allowing for variation in age among the 7 year old sample in 2006 (noted above), the magnitude of the

secular trend in body weight among the four surveys of girls is variable, although girls in 2016 are, on average, heaviest and in 1986 thinnest (Figure 3B).

Re b) Heights and weights differ significantly ($P < .001$) among the four surveys in each age group. Age-adjusted means indicate a reasonably clear gradient across surveys in boys: 2016 > 2006 > 1996 > 1986. However, group comparisons between the terms were not consistent. (Table 2).

Height in boys is significantly greater in 2016 than 2006 at 10 to 12 years group, but does not differ significantly between the two surveys in girls 7 to 9 and 13 to 15 years. There was the following variability 2016 > 2006 > 1996 > 1986, except for the 7-9 years group (2016=2006>1996>1986) (Table 1). In the girls' group, there was no common/ambiguous direction of change. In each age group, increments were observed between different decades (Table 2).

Re c) Over the 30 year interval, estimated secular changes are similar in boys and girls 7 to 9 years and reasonably similar at 10 to 12 years, while corresponding changes are greater in boys than in girls 13 to 15 years (Table 3). Among boys, the highest dynamics of height and weight gains in all age groups of boys occurred between 1996 and 2006, and the differences were statistically significant. The smallest increments were observed in the last decade. In contrast, secular gains in weight of girls 7 to 9 and 10 to 12 years are relatively similar across decennial surveys, but gains in girls 13 to 15 years show a major gain between 1996 and 2006 years after no change between 1986 and 1996.

Summary

The magnitude of the secular changes in the heights and weights of children and youth from increased significant. Estimated rates of secular change, however, varied across the four decennial surveys and between the girls and boys groups.

Publication 2.

Weight Status of Rural School Youth in Poland: Secular Change 1986-2016 Anthropologischer Anzeiger;. 2022 79(1):43–56

The aim was to evaluate the variability of BMI in children aged 7-15 years in four survey dates conducted at decade intervals from 1986 to 2016.

Similar to the first paper, analyses included variation in BMI:

a) across calendar age groups,
b) comparisons between the three age groups across surveys,
c) considering group of weight status - underweight, overweight, and obese.

Re a) The survey showed that in subsequent decades there was a trend of increasing BMI in individual age groups. Increases between the extreme dates took a more linear direction of change in the group of boys than in the group of girls.

Re b) Results of the sex-specific ANCOVAs across the four surveys in each of the three age groups are nonlinear. In each age boys group, BMIs in 2016 and 2006 do not differ, and both are significantly higher than BMIs in 1996 and 1986. Except among boys 7–9 in whom the BMI in 1996 is significantly greater than in 1986 (Table 1). In the girls group, resales were variable across age groups, the greatest variability were observed in the 10-12 age group. However, there was a trend indicating that the variability of results in 2006 (c) and 2016 (d) was higher each time than in previous years (b and a) (Table 1). Overall, BMIs differ significantly ($p < 0.001$) between 1986 and 2016 in each CA group of both boys and girls.

Re (c) The next step of the study was to categorize the weight status groups. Severe and moderate thinness are low in prevalence over time in boys. In contrast, OWT increases in prevalence across surveys in the three age groups of boys and is especially higher in 2006 and 2016 compared to 1986 and 1996 (Table 3). Among girls, the prevalence of severe and moderate thinness is also relatively low, with no clear trend across surveys. OWT increases across surveys among girls 7–9 and 10–12 years. In the oldest age group, the direction of change was the same, but the increment values were lower (Table 3).

Summary

Secular changes in the BMIs of rural boys and girls between 1986 and 2016 were significant, and in most groups suggested a gradient in age-adjusted means: 2016 > 2006 > 1996 > 1986, there was a trend towards a decrease in the prevalence of underweight especially between 1986 and 1996 and an increase in overweight and obesity especially between 2006 and 2016. Changes were variable and not linear over time and between girls and boys groups.

Publication 3.

Age at menarche among rural school youth in west-central Poland: variation with weight status and population growth. Anthropological Review, 2021 84(1), 51-58

The aim was to estimate the age at menarche among girls from the rural region of Wielkopolska in the 2016 and to compere ages at menarche by weight status and by population growth.

The sample included 1146 girls, 7–16 years of age, resident in 10 rural communities. Aanalyses were calculated:

a) for the total sample,
b) for the subsamples of girls classified as Thin, Normal Weight, and Overweight,
c) for samples of girls from the communities which experienced Major and Little/No growth,
d) for samples of Thin and Overweight girls from communities with Major and Little/No growth; numbers of Thin girls by age groups were too small for analysis.

The present study is limited to the 2016 survey during which information on the menarcheal status of girls was surveyed.

Re a) The median age at menarche for the total sample of rural girls in 2016 was 13.25±0.20 yrs.

Re b) Menarche occurred earliest, on average, among Overweight girls (13.06±0.32 years), followed by Normal Weight girls (13.25±0.37 years) and Thin girls (13.81±0.41 years). The difference in ages at menarche between Overweight and Thin girls approached significance; other pairwise comparisons were not significant (Table 1).

Re c) Age at menarche among girls in the former communities was, on average, significantly earlier than that among girls resident in communities Little/No population growth, 12.58±0.44 and 13.65±0.14 years, respectively.

Re d) Among girls from the communities with Major growth, median ages at menarche were 12.12±0.49 years in Overweight and 12.54±0.15 years in Normal Weight girls. Corresponding estimates for the communities with Little/No growth were 13.46±0.40 years in Overweight and 13.62±0.18 years in Normal Weight girls.

Summary

The median age at menarche was earlier in the overweight group compared to the other groups. The effect of change in population size over time on the age of occurrence at menarche was observed.

Publication 4.

Physical Fitness of Rural Polish School Youth: Trends between 1986 and 2016 Journal of Physical Activity and Health, 2021 May 28;18(7):789-800

The aim of the study was to evaluate secular changes in the physical fitness of rural school youth, 7–15 years, in west-central Poland between 1986 and 2016.

According to the guiding idea of the cycle presented also in the first and second article, three relevant criteria of division were adopted in the manuscript 4th:

a) for each survey by sex-specific single year CA groups to illustrate trends over time,
b) comparisons between combined the three age groups across surveys,
c) Sex-specific analysis of covariance, with age and age^2 of each student as covariates, were done in each combined CA group to compare fitness tests across the 4 surveys.

Re a) Speed (Figure 1A) improves, on average, with age among boys from 7 to 15 years in all surveys, but it improves from 7 to 12 years in girls, followed by a plateau. Agility (Figure 1B) shows a similar age-related pattern as speed in boys and girls, respectively, but it should be noted that a lower time indicates a better performance. The vertical jump (Figure 1C) improves, on average, from 7 to 15 years in both sexes. Flexibility (Figure 1D) is best in 1986 and tends to decline across the 4 surveys, more so in boys than girls. Flexibility shows little improvement with age from 7 to 11 years in both sexes (except girls 7 y in 2006). The step test index (Figure 1E) shows no consistent pattern with age among boys and overlaps across surveys. In contrast, the index declines with age among girls and is best at most ages in 2006.

Re b) Performances on all tests across the 30-year span differ significantly in each CA group of boys except for the step test (13–15 yrs.) and in each CA group of girls except for the

vertical jump (13–15 yrs.). Effects sizes (η^2_p) are moderate for the speed test in both sexes, and generally low for the other fitness items in both sexes (Table 1 and Table 2).

Re c) Running speed (in meters per second; Figure 2A) declines between 1986 and 2016 in boys and girls. Speed declines significantly ($P < .05$) between 1986 and 1996, more in boys than girls, and, between 1996 and 2006, more in girls than boys. Changes in speed between 2006 and 2016 are negligible.

Agility (Figure 2B) improves (decease in time) significantly between 1986 and 2016, except among girls 10–12 years. Agility improves significantly ($P < .05$) between 1986 and 1996 in boys and girls in the 3 age groups, while changes between 1996 and 2006 and 2006 and 2016 are variable and significant ($P < .05$) only in boys 13–15 years.

Change in the vertical jump (Figure 2C) between 1986 and 2016 is similar in boys and girls 7–9 and 10–12 years but is considerably larger among boys 13–15 years and negligible among girls 13–15 years. Jumping performances of boys in the 3 age groups increased between 1986 and 1996 ($P < .05$), are variable between 1996 and 2006, and decline between 2006 and 2016 ($P < .05$). After significant gains between 1986 and 1996, vertical jump performances of girls 7–9 and 10–12 years change negligibly or decline between 1996 and 2006 ($P < .05$, 10–12 yrs.) and between 2006 and 2016. Among girls 13–15 years, changes are negligible and not significant between adjacent surveys.

The decline in flexibility (Figure 2D) between 1986 and 2016 is significant in each age group ($P < .05$) and greater in boys than in girls. The declines occur between 1986 and 1996 and between 1996 and 2006 in both boys and girls ($P < .05$ at 7–9 and 10–12 yrs.). Between 2006 and 2016, girls improve in flexibility, though variably among age groups ($P < .05$, at 7–9 yrs.), while boys continue to decline in flexibility ($P < .05$, at 10–12 and 13–15 yrs.). The step test index (Figure 2E) improves slightly but not significantly in girls 7–9 and 10–12 years, but increases significantly in girls 13–15 years between 1986 and 2016 ($P <.05$). The index declines across the 30-year interval in boys 7–9 and 10–12 years, but is, on average, unchanged among boys 13– 15 years.

Changes in the step test index vary considerably between adjacent surveys. The index declines in boys ($P < .05$) and girls 7–9 and 10–12 years but increases in boys and girls ($P < .05$) 13– 15 years between 1986 and 1996. The index then increases in the 3 age groups of girls ($P < .05$ at 7–9 and 10–12 yrs.) but declines in boys 10–12 and 13–15 years between 1996 and

2006. The index changes insignificantly between 2006 and 2016, but the direction is positive in boys and negative in girls.

Summary

As in the case of somatic parameters, no clear trend was observed in the direction of changes in all observed motor skills.

Publication 5.

Relationship between BMI and physical fitness of Polish School Youth: Trends between 1986 and 2016 Acta Kinesiologica 2021, 15 (2):134-143

The aim of the present study was twofold: first, to compare the fitness of Thin, Normal weight and Overweight/Obese youth 7-15 years of age across four surveys spanning 1986 through 2006, and second, to evaluate relationships between each fitness item and the BMI in the four surveys.

The detailed search were concentrate on the two areas, as follow:

a) performances on each fitness test were compared among Thin, Normal weight and Owt/Ob youth within and among surveys,
b) sex-specific regressions of each fitness test on the BMI were done by survey using linear and nonlinear quadratic models.

Re a) Fitness test performances differ significantly among the three weight status groups of boys and girls, with the exception of flexibility among boys 7-9 years and boys and girls 10-12 years. Performances also differ significantly among surveys except for CV fitness among boys 7-9 and 13-15 years and explosive power among girls 13-15 years. However, interactions between weight status and year of survey are not consistently different and show no clear pattern among fitness test in both sexes (Table 1).

Although not consistent for all comparisons, post hoc comparisons suggest poorer performances on all fitness tests except flexibility among Owt/Ob compared to Normal and Thin boys (Table 2). Comparisons of fitness performances within weight status groups across surveys, however, are variable except for speed. Running speed is generally similar between

1986 and 1996 and between 2006 and 2016, but is significantly better in 1986 and 1996 compared to 2006 and 2016. CV fitness is also better in the two younger age groups in 1986.

Corresponding post hoc comparisons among girls, indicate consistently poorer performances in explosive power among Owt/Ob girls 10-12 and 13- 15 years, while performances of Thin and Normal girls do not consistently differ (Table 3). Running speed in girls shows a pattern that is similar to that in boys, i.e. similar performances 1986 and 1996 and in 2006 and 2016, but significantly better performances in 1986 and 1996 compared to 2006 and 2016. Performances on the other fitness tests within weight status groups are, as in boys, variable across surveys and show no consistent trends.

Re b) Results of the regression analyses are summarized in Tables 4 (boys) and 5 (girls). Most of the regressions had a very low explained variance (R^2) and several are not significant. Relationships between the BMI and fitness performances also vary across the four surveys. Nevertheless, the quadratic coefficients are significant in some models, indicating that the association between the BMI and the specific fitness test is curvilinear. This suggests that better performances are generally attained by youth with BMIs in the mid-range of the distribution, while performances of those at the low and high tails of the BMI distribution are lower. This is apparent for relationships between the BMI and speed, agility and explosive power in the 1986 survey except among girls 7-9 years. On the other hand, a curvilinear relationship is suggested across the four surveys for all tests except CV fitness among boys 13-15 years.

Summary

The results suggest reasonably consistent curvilinear relationships between performances and the BMI in boys more so than in girls, but the explained variances were generally low. This result suggests that typically higher scores were obtained by children and adolescents with BMIs in the middle range of the BMI distribution.

5. Discussion

The presented series of publications describes issues related to changes in height, weight, BMI, age at menarche and fitness levels, as well as the existence of relationships between weight groups and level of physical fitness.

Studies describing changes in the somatic parameters in groups of Polish children and adolescents were presented in a variety of study. Some present comparisons for single year age groups, but delineation of the age group varies to some extent, i.e., 7.0; 8.0... 15.0 years (Gomuła et al., 2015) or 7.5; 8.5; 15.5 years (Przewęda and Dobosz, 2003; Kowal et al., 2011). Others have presented data from combined age groups, e.g., 7-9, 10-12, 13-15 years (Ignasiak et al., 2016). Studies also presented analyses from a national perspective (Przewęda and Dobosz, 2003; Gomuła et al., 2015), and region of residence, including social groups and area of residence, i.e., urban and rural (Krawczyński et al., 2003; Saczuk, 2018; Wilczewski, 2005; Wilczewski and Wilczewski, 2018).

Height, weight, and age at menarche in successive decades from 1986 to 2016 showed similar trends of change as noted in studies which considered similar time intervals for national samples of children and adolescents in the Polish population (Przewęda and Dobosz, 2003; Gomuła et al., 2015), and also in specific cities and regions of Poland, including samples from three cities Poznań (Krawczyński et al. 2000; 2003), Kraków (Kowal et al. 2011) and Rzeszów (Perenc, Radochonska, and Błajda., 2016), and largely rural samples in eastern Poland (Saczuk., 2018; Wilczewski., 2005; Wilczewski and Wilczewski 2018).

It should be noted, however, that estimated changes in the heights and weights of each age group of rural boys and girls in the 10 communities between 1986 and 2016 were comparable with and overlapped those noted in national samples between 1988 and 2012 (Gomuła et al., 2015). On the other hand, changes in the heights and weights of each age group of rural boys and girls in the 10 communities between 1986 and 1996 were somewhat less than corresponding changes in national samples between 1989 and 1999 (Przewęda and Dobosz, 2003). By inference, secular gains were variable and not linear over time and region of residence may be an influencing factor.

BMIs of rural boys and girls increased, on average, across four decennial surveys of the same ten communities spanning. Relative to 2010 reference data for Poland (Kułaga et al. 2011), median BMIs of rural boys in 2016 approximated the medians at 7 and 8 years. Median

BMIs of girls in 2016 tended to be above the reference medians at most ages. Median BMIs of the rural boys and girls 10–15 years in 2006 and 2016 overlapped those for a combined sample of urban and rural boys and girls in the Greater Poland province surveyed in 2009–2010 years (Kaczmarek et al., 2011).

The prevalence of OWT and OB increased across surveys, and was especially higher in 2006 and 2016 compared to 1986 and 1996. The observed trends for overweight and obesity were consistent with national competition with studies conducted in 1996, 1978, 1988 and 2012 (Gomula et al., 2015), in 2001 (Małecka-Tandera et al., 2005) and in 2010 years (Kaluga et al., 2011). A similar almost linear increase in values was also observed by researchers among children from Kraków, where surveys were conducted in 1971, 1983 and 2000 years (Chrzanowska et al., 2007). The same trend was observed in different regions of our country, in Podlaskie Province in 1986 and 2006 (Saczuk and Wasiluk, 2014) and in Podkarpackie Province in 1998 and 2008 years (Mazur et al., 2014).

The above-described directions of changes were observed both boys and girls group in 7-9 and 10-12 year. In the girls group 13-15 year, the direction of changes was the same, however increases was significantly lower, which could be due to the earlier maturation of girls and the emerging awareness of body perception, which is one of the key elements shaping the personality of a maturing person (Malina et al., 2004).

The prevalence of severe and moderate thinness was relatively low over time in both boys and girls with no clear trend across surveys. In subsequent surveys, the number of children in this group decreased in 2016 and 2006 compared to 1986 and 1996 year. Current surveys focus, however is more often upon OWT and OB, which the World Health Organization (WHO) has identified as one of the most serious chronic diseases of the 21st century (Ng et al., 2014). In contrast, secular data for underweight, categorized into severe, moderate, and mild, are limited. Secular data for thinness are limited. Estimated prevalence of severe, moderate and mild thinness among rural boys and girls 13–15 years in the 2016 year survey was similar to that for a sample of urban and rural boys and girls 13–18 years from the Greater Poland province in 2009–2010 years (Durda, 2011). Mild thinness was relatively more common in 1986 and declined slightly in 2006 among youth 10–12 and 13–15 years. In contrast, mild thinness was rather high among rural Poznań children 7–9 years in 1986 (boys 15.6%, girls 13.4%), but declined in 2016 year (boys 4.1%, girls 7.3%). Estimates for mild thinness among children 7–

9 years in the Podlaskie province were lower in 1986 (boys 7.3%, girls 11.5%) and changed negligibly in 2006 years (boys 8.9%, girls 12.8%) (Saczuk and Wasiluk, 2014).

To summarize the above observations, at the lower end of the BMI range, the prevalence of severe and moderate underweight was very low in four surveys of observation in both boys and girls group, while the prevalence of mild underweight was relatively low in all observations, except for boys and girls aged 7-9 years in 1986 year. On the other hand, the prevalence of overweight was higher in 2006 and 2016 compared to 1986 and 1996 among boys and girls in the three age groups, while the prevalence of obesity was lower. A potential reason could be the change in eating habits and sedentary lifestyle of young people.

The median age at menarche in the rural population in 2016 was 13.25 years. It was similar to ages at menarche in rural girls from families of farmers (13.32±1.98 years), of farm-workers (13.19±1.67 years) and of non-farmers (13.17±1.96 years) resident in four geographic regions of Poland in 2001 (Łaska-Mierzejewska and Olszewska, 2007). The age at menarche of the 2016 sample of rural girls in the present study was slightly later than ages at menarche noted among girls 7–18 years resident in small towns years and in rural villages, years in a 2012 survey of seven districts in Poland (Gomula and Kozieł, 2018).

Weight status and by inference nutritional status is a factor related to age at menarche. In the current study, girls classified as overweight attained menarche at a median age of 13.06 years, followed by normal weight girls at 13.25 years, and thin (underweight) girls at 13.34 years. The observations were consistent studies in other countries and regions concluding that overweight girls mature earlier (Anderson and Must, 2005; Biro et al., 2018; Bratke et al., 2017; Himes et al., 2009; Lazzeri et al., 2018). In a longitudinal series of urban girls in Poznąń, ages at menarche were 12.33±1.46 years among 38 overweight girls, 12.48±0.92 years among 172 normal weight girls, and 13.90±0.13 years among 33 underweight girls (Durda-Masny et al. 2019). Comparing girls living in rural areas around Poznań with those living in the city, one may notice that thin or underweight girls develop at a similar rate; however, those classified as normal weight and overweight mature, on average, earlier in the city than in the country.

The median age at menarche was significantly differentiated according to changes in population size over the 30-year observation period. In the group of girls who lived in areas with an observed increase in population size the median age at menarche was 12.58 years, and was lower compared to Little/No population grow - 13.65 years. The communities which

experienced a major population increase were located relatively close to Poznań, 19 to 37 km, while those which experienced little or no population increase were located a bit further from Poznań, 37 to 75 km. It can be assumed that the probable reason for the observed variation in the age at menarche could be migration of the population from the city to its suburbs. As a result of this process, the rural area becomes similar to the urban area and this phenomenon is called semiurbanization of the countryside (Brańka, 2014). This assumption may be confirmed by information on the number of births in the observed localities. Data from the statistical yearbook indicated that only one of the five communities which experienced major growth showed an increase in birth rates while among the remaining nine communities, changes in estimated birth rates were negligible in three an declined in the other six.

Changes in the physical fitness status of rural boys and girls across the 4 decennial surveys spanning 1986 through 2016 varied among the 5 tests. Speed (5-m sprint) and flexibility (stand and reach) declined, while power (vertical jump) and step test index (cardiovascular fitness) changed variably. On the other hand, agility (figure of 8 run) improved across the 4 surveys; although, the major improvement occurred between 1986 and 1996. The changes contradict the commonly held opinion that the level of physical fitness is decreasing. The above changes may indicate a change in the structure of motor skills, but do not indicate a complete deterioration.

The variable changes in fitness contrasted positive secular changes in height and weight of the rural youth in the 10 communities, and may reflect increases in the BMI and changes in weight status between 2006 and 2016 years in the rural school youth. Trends in the fitness of rural school youth in the 10 communities were generally consistent with other surveys in Poland that spanned all or part the interval considered in the present study. In national samples, for example, the Cooper test, strength, and standing long jump declined or did not change across surveys in 1979, 1989, and 1999 years (Przewęda and Dobosz, 2007; Przewęda, 2009). Regionally, speed, endurance, strength, and agility (lesser extent) declined between 1965 and 1995 years among youth in Upper Silesia (southwestern Poland) (Raczek, 1997). Power, speed, and agility improved while agility declined between 1971 and 1981 years in youth from the Bydgoszcz region (north central), but all fitness items declined between 1981 and 1991 (Nowicki, 1996). Among school youth in eastern Poland, several indicators of fitness declined between 1986 and 2006 (Saczuk, 2018) and between 1986 and 2016 years (Wilczewski and Wilczewski, 2018). Among urban Cracow youth, sit-ups, the standing long jump, and sit and reach performances declined between 1980s and 2000 years, while the overhead medicine ball throw and standing long jump changed variably between 1975–1980 and 2005–2010 years in

youth from Cracow and a small town and village (Mleczko, 2013). Trends noted among Polish youth were generally consistent with trends in other country (Tomkinson et al., 2007; Tomkinson et al., 2014; Dooley et al., 2020; Smpokos et al., 2012; Ao et al., 2019).

Comparison among weight status groups indicated, on average, poorer performances on all fitness tests except flexibility among Owt/Ob compared to Normal and Thin boys and girls. On the other hand, performances on the five fitness tests were generally similar within the samples of Thin, Normal weight and Owt/Ob youth across the four surveys. By inference, there were no consistent secular trends in fitness performances within weight status groups. Results of the regression analyses were quite variable and likely reflected the concentration of the sample within the normal weight range with proportionally fewer youth at the extremes of the BMI distributions. Nevertheless, results of the regression analyses in the present study were reasonably consistent with trends suggested in the literature. For example, results for the rural youth 13-15 years in 2006 and 2016 years were generally consistent with a similar analysis of relationships between the BMI and fitness among school youth 13-15 years resident in an urban-rural administrative district about 110-120 km east-southeast of Poznań (Kwieciński et al., 2018). Although different fitness tests were used, the results were consistent in showing curvilinear relationships with the BMI for tests of speed (50 m dash, 5 m sprint), agility (shuttle run, figure-8-run), and explosive power (standing long jump, vertical jump) in both sexes. For flexibility (standing forward bend/reach), results were curvilinear in boys and linear in girls in both studies. In contrast, results varied for the tests of cardiovascular endurance, 1000 m (boys) and 800 m (girls) runs compared to the step test (in present study).

A curvilinear relationship was noted for the vertical jump in the rural Polish school youth in the three age groups in 1996 and for the standing long jump in a 1997 national sample of Taiwan girls 9-10, 11-12 and 13-15 years and boys 11-12 and 13-15 years of age (Huang and Malina, 2010), the relationship was linear among Taiwan boys 9-10 years. For CV fitness, curvilinear relationships were noted for the 800 (girls) and 1600 (boys) meter run-walk in Taiwan youth and for the step test in Polish youth 13-15 years. Linear relationships in both studies were noted for the 800 meter run-walk in Taiwan youth 9-10 years and for the step test in Polish youth 7-9 years, while results were variable among Taiwan youth 11-12 years and Polish youth 10-12 years. On the other hand, results in the two studies varied for flexibility, curvilinear for the sit and reach for Taiwan boys and girls, but variable for the stand and reach in Polish youth.

In contrast, results for Polish youth in 2016 and Brazilian youth in 2013 (Lopes et al., 2019) were variable. Among Brazilian youth of both sexes, the relationship between the standing long jump and BMI was curvilinear among youth of both sexes 10-11 and 12-13, but was curvilinear among boys and linear among girls 14-15 years. Among Polish youth, the relationship between the vertical jump and BMI was linear at 10-12 years but curvilinear at 13-15 years in both sexes. For cardiovascular fitness, the relationship was linear between the BMI and multi-stage shuttle run in Brazilian girls 10-11, 12-13 and 14-15 years, but that between the BMI and step test in Polish was curvilinear among girls 10-12 years, but linear among girls 13-15 years.

The difficulty in finding analogies or differences with respect to the results of other studies stems from the fact that different batteries of tests are used during the observations made. However, on the other hand, if they are used to assess the same aspect of fitness, some comparisons can be made with respect to the nature (aerobic, anaerobic) of the ability tested.

In summary, the results of the correlations between fitness tests and BMI varied across age groups and study dates, and one likely reason for this distribution of results may be the concentration of adolescents in the normal range of body mass and their proportionately smaller participation in both extremes of the range - underweight and overweight. However, analyses generally suggest fairly consistent curvilinear relationships between test scores and BMI, occurring more frequently in boys than in girls.

Political and economic changes in Poland

The observed changes in somatic structure, rate of maturation and physical fitness should be considered in the context of the major political, economic and social changes that took place in Poland during the period of survey. As noted earlier, the 1986 year survey was done during the interval between major strikes and political unrest in the early 1980s, the collapse of the communist government, and the first democratic elections in 1991 year.

Subsequent surveys spanned significant political, economic and social transitions associated with adaptation to a western democratic system. Although community specific data are not available, it is reasonable to assume that changing and perhaps variable conditions in each community across surveys interacted with the transitions occurring in Poland in general,

which contributed to variation in estimated rates of secular change. Changes in the economic and agricultural sectors and their interactions are relevant to discussions of secular change given potential impact on nutritional and health status. Moreover, changes in the agricultural sector are especially relevant given that the communities studied were agriculture-dependent. Although the Polish economy was gradually incorporated into the international and global economic system during interval of the four surveys (Urbanowska-Sojkin and Banaszyk, 2009).

The need to repay foreign debt led to a deficit of goods in the domestic market, a halving of real income, and inflation (Gomuła et al., 2015; Saczuk, 2018) affected the economic state of the Polish population. The political transition also had a major impact on Polish agriculture. With the transition to a market economy in 1991 year, State Agricultural Farms were abolished. In 1980 year, state farms employed approximately 490 per 1000 individuals, and on average, state farms employed 12 people per 100 ha. More than 50% of state funds allocated to agriculture went to state-owned farms until 1988. The price per unit of products produced by farmers in 1990 to 1991 years declined by 63%, while real farm income declined >40% and wages of employees declined by about 37% (Kowalik, 2009).

As noted earlier, the region comprising the 10 rural communities had a high proportion of state-owned and cooperative farms in the 1980s (Banski, 2010). Two communities had state-owned farms (Pamiątkowo and Kwilcz) and one had a cooperative farm (Wojnowice). The others did not have state-owned or cooperative farms, but were located relatively short distances from state farms (4-10 km). It was reasonable to assume that some residents worked on the state-owned or cooperative farms; the communities also had small family-owned farms. One community (Biedrusko) was adjacent to a military base (Database of the National Support Centre for Agriculture, 2019) and likely benefited from jobs associated with the base.

State and cooperative farms also influenced the social life in the rural communities, and in many ways ensured that the needs of employees and their families were met. With the liquidation of state farms in the 1990s and associated political and economic changes, the structure and services of rural communities were also affected. Perhaps the most relevant, among other changes, was the reduction in bus connections and railway lines, and closure of some primary (grades 1-3) and elementary schools (grades 1-6) in the 1990s. Schools in the 10 communities of the present study were not affected by the closures. Although family farms were generally more productive during the reforms and many actively joined the developing

market economy, alcoholism, passivity and perceptions of helplessness increased in many rural communities as overall agricultural conditions deteriorated (Górecki., 2015; Halamska., 2011).

The Agricultural Property Agency provided a program for former employees on state farms between 1991 and 2004 years. The number of unemployment claims indicating state-owned farms as the last place of employment was 100 000 in 1991 year, but declined by about one-half in 2004 year as approximately 48 000 of unemployed individuals received a job or a job offer. In addition, about 1.2 billion Polish złoty were spent on various forms of assistance for those who worked on state farms between 1999 and 2004, including educational scholarships. Former state farm employees were also offered an opportunity to purchase an apartment at preferential rates (Zgliński, 2003).

Access to the European Union in 2004 was important for Polish agriculture as Poland was included with the Common Agricultural Policy (CAP). The policy involved the introduction of direct payments to farmers for their crops and facilitated acquisition of agricultural machinery at reduced prices. On the other hand, the number of small farms which produced food items for personal use was reduced, and the rural population declined during the political and economic transition. The rural population comprised 52% of the national population of Poland in 1960, declined to 41% in 1980 year (i.e. time of the strikes and political unrest), and was stable through 1990 (38%) and 2016 years (40%) (Statistical Yearbook of Poland, 2017).

Of relevance, how these changes and others influenced living conditions in the specific communities and in turn the growth status of school children in the respective communities across the surveys spanning the 30 year interval merits attention.

The market transformation likely contributed to an improvement in the quality of education in rural areas, and the number of young adult rural residents with a higher education increased over time. Based on questionnaires completed by the parents of children and youth in the four surveys comprising the present study, the majority of parents had only an elementary education in 1986 year (~77% of both fathers and mothers). Over the 1996 and 2006 years surveys, the proportion of fathers with only an elementary education declined only slightly (75% and 73%, respectively), while the proportion of mothers with only an elementary education declined more so (67% and 57%, respectively). Across the first three surveys, on the other hand, the percentages of mothers with a technical or secondary school education increased steadily, 22%, 29% and 38%, respectively, but the corresponding percentages of fathers

changed only slightly, 19%, 19% and 23%, respectively. The proportion of parents of both sexes with a higher education across the first three surveys was 3% in 1986 and 5% in 1996 and 2006 years, but the educational status of parents of the school children in 2016 year changed considerably. Percentages of fathers with an elementary, technical/secondary, or higher education in 2016 were 54%, 30%, and 15%, respectively, while percentages among mothers were 37%, 39%, and 24%, respectively (Bartkowiak et al., 2021a).

However, it is difficult to evaluate the specific impact of the political, economic and social changes in Poland on nutritional habits and physical fitness, two factors often identified as important in discussions of changes in body weight, BMI and fitness levels (Przewęda., 2009; Gomuła et al., 2015; Gomuła and Koziel, 2018). As inflation increased during the 1970s, access to food products was limited and food rationing was instituted in the mid-1970s, first for sugar, then for meat and meat products, and eventually for butter, flour cereal and rice. Families were allocated vouchers or ration cards that were in force until 1989 (Zawistowski, 2017). In rural areas, rationed foods were often supplemented with foods produced for personal consumption (milk, butter, eggs, chicken, duck, pork) and by barter (meat for butter, eggs for milk, etc.). After the political changes of the 1980s and gradual opening of the market, processed foods regularly entered Poland.

Another important factor may be differences in the daily food rations of school children. In the city of Poznań showed minor differences between 1980 and 1990 years. The estimated average daily consumption of calories and specific nutrients among girls 13–15 years was 2278 ± 628 kcal (61 g protein, 102 g fat, 280 g carbohydrates) in 1980 year and 2144± 728 kcal (59 g protein, 87 g fat, 282 g carbohydrates) in 1990 year. Daily estimates for boys 13–15 years were 2597 ±879 kcal (74 g protein, 121 g fat, 303 g carbohydrates) in 1980 and 2538 ± 848 kcal (68 g protein, 105 g fat, 331 g carbohydrates in 1990 (Przysławski et al., 1998).

Surveys of eating habits and food consumption among adolescents suggested an increase of processed and “fast foods” between 1990 and 2000 years (Augustyniak and Brzozowska, 2002). Although rural adolescents consumed fewer calories than urban peers, both groups showed an increase in energy from fat and a decrease in energy from carbohydrates and proteins, while daily intakes were deficient in minerals – calcium, magnesium, copper and especially iron among girls. More recently, the percentage of Polish youth 13–15 years consuming vegetables daily changed negligibly between 2002 and 2018 years, 36.6% to 34.2%, while percent ages consuming fruits daily increased, 23.1% to 38.2%; on the other hand,

percentages consuming sweets and sweet drinks increased more than threefold between 2002 and 2018 years, 18.1% to 69.9% and 12.7% to 44.9%, respectively (Augustyniak and Brzozowska., 2002; Woynarowska and Mazur., 2012; Mazur., 2015; Mazur and Małkowska-Szkutnik., 2018).

The above trends, while interesting, are largely limited to youth and do not account for potential differences between rural and urban youth. Nevertheless, consumption of sweets and sugary drinks may have contributed to the increased prevalence of overweight and obesity among children and adolescents in rural settings between 1996 and 2016 years.

Changes in diet over time can affect body weight, which is potentially one of the determinants of physical fitness and age at menarche, especially at the upper extremes of BMI. Physical activity is also an important component. Data addressing levels of physical activity among Polish children and youth are apparently not available prior to 1990 year, while recent data are largely limited to adolescents. Estimated percentages of 11, 13 and 15 year old boys reporting vigorous physical activity (VPA) 4–7 days per week between 1990 and 1998 years were 54%, 51% and 42%, respectively, but declined in 2018 year to 43%, 37% and 35%, respectively. By inference, percentages of boys not reporting VPA 4–7 days per week increased over time. Percentages of girls reporting VPA were lower and declined negligibly between the 1990s and 2018 year, 38% to 36% at 11 years and 31%, to 27% at 13 years Among girls 15 years, percentages reporting VPA 4–7 days per week were lower and stable over time, 20% in the 1990s and 22% in 2018 year (Woynarowska and Mazur, 2012; Mazur, 2015; Mazur and Małkowska-Szkutnik, 2018).

With a modified indicator moderate-to-vigorous physical activity (MVPA), which included mandatory school physical education (4 hours/week since 2003 yr.), percentages of Polish boys reporting MVPA seven days per week in five surveys spanning 2002 to 2018 were rather low, 24% to 34% at 11 years, 16% to 29% at 13 years and 16% to 25% at 15 years. Percentages of girls reporting MVPA seven days per week across the same interval were lower, 18% to 27% at 11 years, 12% to 18% at 13 years, and 8% to 11% at 15 years. Declines in physical activity were accompanied by an increase in sedentary activities. Allowing for slight variation across surveys spanning 2000 and 2018 yrs., >50% Polish youth 11 to 15 years spent ≥2 to 3 hours per day watching TV/videos on school days, with more doing so on the weekend. Percentages of youth spending ≥2 to 3 hours per day at computer games were relatively low on school days, especially among girls, but 46% to 58% of boys 13–15 years reported 4+ hours

playing computer games on weekends with little variation across surveys (Woynarowska and Mazur, 2012; Mazur, 2015; Mazur and Małkowska-Szkutnik, 2018).

In an independent survey in 2011, >50% of Polish middle and high school youth spent ≥3 hours per day watching TV or on the computer. By inference, the overwhelming majority of Polish youth 11–15 years did not report MVPA on a daily basis between 2002 and 2018yrs. Of note, high levels of VPA and MVPA are associated with a lower risk of obesity independent of sedentary behaviour (Katzmarzyk et al., 2015).

It is difficult to evaluate the changes in youth fitness in the context of the economic and social changes associated with the government transition in the 1980s and subsequent years. It is reasonable to assume, however, that the changes influenced education. Physical education which was compulsory at 2 hours per week was increased to 3 hours per week in 1997 yr. and to 4 hours per week in 2002 yr. Of the latter requirement, 3 hours per week of school physical education were mandatory, while the fourth hour was optional and dependent upon local opportunities outside of the school setting, for example, swimming classes, running in the forests, skiing, and so forth (Janowski, 2017; Woynarowska, 2008). Assessment in physical education was expanded to include basic motor skills and coordination in addition physical fitness. Over time, assessment of motor skills and fitness was increasingly placed in the context of physical activity with the goal of preparing school youth for lifelong physical activity (RMEN, 2017). Implementation of the changes in physical education, however, varied considerably despite detailed evaluation programs and systems. A national audit in 2010 indicated several irregularities. Between 2007 and 2009 years, for example, the physical education curriculum in more than one-half of schools in Poland was not modified to meet government regulations, while the new core curriculum for 2009–2010 yrs. was not implemented in 20% of schools. Of relevance to the present discussion, the national audit noted that two-thirds of schools did not monitor student progress in physical education, including fitness testing. It was also estimated that 20% to 40% of school youth participated in fewer physical education classes and physical activities than required by law, and the trend increased with the age of students (Woynarowska et al., 2015).

Given the economic and political transformations in Poland and associated social, occupational and educational changes, the Polish family and living conditions have changed, especially between 2006 and 2016. Perhaps the most significant was the reduction in multi-generational families and in the number of children in the family. The trends likely reflect the

results of the choices of young people who were increasingly investing time in education in an effort to attain a level of education that would provide economic stability, including an increase in the number of working-mothers. The changes undoubtedly influenced responsibilities for child care and after school activities of children (Bienkowska and Kitlinska-Król, 2017).

The observation did not exhaust the entire subject, but the results obtained indicate the continuing validity of the research undertaken in this area. What is more, new and so far unmentioned topics have appeared in the literature, which will serve to continue and extend the research presented in this dissertation.

In summary, it is possible that political changes and related economic and social uncertainty in Poland during the period between the surveys may have affected living conditions in 10 communities and families in particular, which in turn may have contributed in part to changes in children's height and weight, age at menarche, and increased prevalence of overweight and obesity in the 2006 and 2016 yrs. surveys. It may also seem true to say that the living conditions of children in the 2006 and 2016 yrs. surveys improved compared to the living realities of children in earlier surveys, as evidenced by the decreasing age of first menstruation. Changes in physical fitness were generally consistent with the observed regression in the level of physical activity and the increase in the frequency of passive physical leisure activities among Polish adolescents since the 1990s. Changes in diet associated with increased consumption of highly processed foods, fast foods and sugary drinks and an increasingly sedentary lifestyle may also have an impact on the observed parameters. The uniqueness of this research project lies in the fact that schoolchildren were surveyed four times in exactly the same 10 locations

6. Limitations

The study is not without limitations. One was the lack of an indicator of biological maturity status, while two others were the lack of specific information on the physical activity and dietary habits of children in rural villages during the first three surveys. Given the lack of such information, it is difficult to evaluate the interactions among changes in body size, physical fitness and environmental changes in the respective communities.

7. Conclusions

Based on the analyses, the following conclusions were developed:

C1. During the thirty-year period of observation of children from the Wielkopolska region, changes in height and weight, as well as weight and growth index (BMI) were found. All the above-mentioned somatic traits increased statistically significantly between the extreme observation dates. However, as far as body height is concerned, the changes are positive, which may indicate improvement of living conditions, but the increase of body weight and BMI, especially the number of overweight and obese children, is a negative tendency which may lead in later years to the occurrence of many civilization diseases in the observed population.

C2. The analysis of the results taking into account relations between weight status groups and the age at menarche allowed us to state that in the observed population the earliest puberty took place in overweight girls, next in the group of normal weight girls and the latest in the group of underweight girls. The median age of first menarche was highly differentiated according to population changes over the 30-year observation period. In the group of girls living in areas with population growth, the median age at menarche was lower by about a year compared with the group from communities with little/no population growth.

C3. During the thirty-year period of observation in children from the Wielkopolska region, changes were found in the value of the results obtained in agility tests determining the level of particular motor abilities. The observed changes were ambiguous, taking different directions and sizes between successive decades of observation. Only in the agility test a systematic progression of the results was observed. The analysis of the results showed that there are changes in the structure of motor abilities in subsequent decades of the study, and not only a decrease in the level of physical fitness.

C4. Over a thirty-year period of observation of children from the Greater Poland region, a nonlinear relationship between BMI and individual motor abilities was found in most cases. The results differed according to age groups and study dates. The probable reason could be the concentration of the number of adolescents in the group with normal body weight and proportionally smaller percentage of children in both extreme ranges - underweight and overweight.

C5. On the basis of a detailed analysis of the results of the study it was concluded that there are specific periods of enhanced development of both somatic characteristics and motor abilities in both sexes. Their course is not linear and differed over the three decades in individual age groups and between groups of girls and boys. No single trend of change during periods of enhanced development was observed in the context of socio-economic change.

Piśmiennictwo / References

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Streszczenie

Sylwia Bartkowiak: Zmiany w rozwoju somatycznym i motorycznym dzieci z regionu Wielkopolski w kolejnych dekadach od 1986 do 2016 w świetle wybranych zmian środowiskowych.

Celem obserwacji było określenie wielkości i kierunków zmian w rozwoju wybranych cech somatycznych i zdolności motorycznych dzieci i młodzieży ze środowiska wiejskiego regionu Wielkopolski oraz poszukiwanie ich prawdopodobnych przyczyn środowiskowych w aspekcie społeczno-gospodarczym.

Metody: Dokonano pomiarów wysokości i masy ciała oraz obliczono BMI dzieci i młodzieży szkolnej w wieku od 7 do 15 lat z 10 miejscowości wiejskich z okolicy miasta Poznania. Wykonano również 5 testów sprawności fizycznej. Badania przeprowadzono w czterech seria w odstępach dekadowych. Badaniami bezpośrednimi objęto 1986 roku 1417 chłopców i 1326 dziewcząt, 1996 roku 979 chłopców i 947 dziewcząt, 2006 roku 871 chłopców i 843 dziewcząt oraz w 2016 roku 1189 chłopców i 1105 dziewcząt. Wykonano statystyki opisowe dla poszczególnych grup wieku kalendarzowego. W celu wykonania bardziej szczegółowych analizy próbę podzielono na trzy grupy wiekowe (7-9, 10-12, 13-15 lat), wykonano analizę ANCOVA z uwzględnieniem wieku i wieku^2 jako zmiennych zależnych dla płci. Dokonano oceny porównań post hoc między poszczególnymi badaniami, z uwzględnieniem korekty dla wielokrotnych porównań (Bonferroni). Następnie wykonano analizy regresji pomiędzy grupami stanu odżywienia oraz wynikami poszczególnych testów sprawności fizycznej za pomocą analizy kowariancji z uwzględnieniem płci przy użyciu liniowych i nieliniowych modeli kwadratowych.

Wyniki: wysokość i masa ciała oraz BMI młodzieży szkolnej z terenów wiejskich zwiększyła się znacząco w latach 1986-2016, ale kierunki zmian pomiędzy sąsiednimi terminami badań były zmienne i nie przebiegały w sposób liniowy. Częstość występowania niedowagi była niska u obu płci. Nadwaga i otyłość zwiększały się z czasem, zwłaszcza w latach 2006 i 2016. Mediana wieku występowania pierwszej miesiączki dla całej próby dziewcząt wiejskich wynosiła 13,25 lat. Menarche występowała wcześniej u dziewcząt z nadwagą niż u dziewcząt z prawidłową masą ciała i u dziewcząt szczupłych oraz u dziewcząt zamieszkałych w gminach o dużym wzroście populacji, które dojrzewały średnio wcześniej o rok w porównaniu z dziewczętami z grupy o małym przyroście populacji lub jego braku. Obserwacje zmian poziomu wybranych zdolności motorycznych wykazały, że wyniki

w testach szybkość i gibkość obniżyły się, a poziom skoczności i wydolności zmieniał się w sposób zróżnicowany w poszczególnych terminach obserwacji. Pomimo, że wartości uzyskiwane w teście gibkości wzrastają to wyniki w pozostałych testach były na ogół niższe niż w wcześniejszych terminach badań. Wyniki były na ogół niższe wśród młodzieży z nadwagą i otyłością w porównaniu z młodzieżą z masą ciała w normie i z niedowagą, Jednakże nie zaobserwowano jednego kierunku zmian w wynikach poszczególnych testów sprawności fizycznej.

Wnioski: W latach 1986-2016 nastąpiły istotne zmiany sekularne w wysokości i masie ciała uczniów szkół wiejskich w 10 gminach wiejskich, ale tempo zmian w kolejnych terminach badań było zróżnicowane. Zmiany wartości BMI w latach 1986-2016 były znaczące. Średnie BMI skorygowane o wiek sugerowały następujący przebieg zmian 2016 > 2006 > 1996 > 1986. Obserwowane zmiany w zakresie nadwagi i otyłości w latach 1986-2016 były zgodne z wynikami badań prowadzonych w Polsce w ciągu ostatnich dwóch pokoleń. Wiek występowania menarche, były zgodny z wynikami ostatnich badań dziewcząt wiejskich w Polsce oraz dziewcząt klasyfikowanych według statusu odżywienia. Wyniki uzyskiwane w 5 testach sprawności fizycznej zmieniały się istotnie, jednakże kierunek zmian nie był liniowy. Relacje między wskaźnikiem BMI a poszczególnymi zdolnościami motorycznymi sugerowały na ogół spójne krzywoliniowe zależności. Wyniki były generalnie zgodne z innymi badaniami polskiej młodzieży szkolnej, które obejmowały podobny przedział czasowy.

Abstract

Sylwia Bartkowiak: Changes in the somatic and motor development of children from the Wielkopolska region in subsequent decades from 1986 to 2016 in the context of selected environmental changes.

The aim of the study was to determine the magnitude and direction of changes in the development of selected somatic characteristics and motor abilities of children and adolescents from rural areas of the Wielkopolska region and to search for their probable environmental causes in socio-economic terms.

Methods: Heights and weights, BMI of school youth 7 to 15 years in 10 rural communities in the vicinity of the city of Poznan were measured and 5 fitness test was evaluated in 1986 (1417 boys, 1326 girls), 1996 (979 boys, 947 girls), 2006 (871 boys, 843 girls), and 2016 (1189 boys, 1105 girls). Descriptive statistics for sex-specific single year chronological age groups were calculated by survey, while the sample was partitioned into three age groups (7-9, 10-12, 13-15 years) for detailed analysis of changes across surveys using sex-specific ANCOVA with age and age^2 as covariates. Pairwise post hoc comparisons between specific surveys, adjusted for multiple comparisons (Bonferroni), were evaluated. Fitness items were compared among weight status groups and across surveys with sex-specific analyses of covariance. Regressions of each fitness item on the BMI in the four surveys were done using linear and nonlinear quadratic models.

Heights and weights of rural school youth increased significantly between 1986 and 2016, but estimated secular gains between adjacent survey were variable and not linear over time. BMIs increased, on average, across the four surveys, but differences between adjacent surveys varied. Prevalence of severe and moderate thinness was low in both sexes, while mild thinness tended to decline over time, more so among girls. Overweight and obesity increased over time, especially in 2006 and 2016 compared to 1986 and 1996. The median age at menarche for the total sample of rural girls was 13.25±0.20 years. Menarche was earlier among Overweight, compared to Normal Weight and Thin, and among girls resident in communities with Major population growth (12.58±0.44 years) compared to Little/No growth (13.65±0.14 years). Speed and flexibility declined, while the jump and step test index changed variably across surveys. Although agility improved across surveys, the major improvement occurred between 1986 and 1996. Performances on all fitness tests except flexibility were poorer among Owt/Ob compared

to Normal and Thin youth, but performances on fitness tests within weight status groups did not differ consistently across surveys.

Conclusion: Significant secular changes occurred in the heights and weights of rural school children in the 10 rural communities between 1986 and 2016, but estimated rates of change across sequential decennial surveys were variable. The results were generally consistent with corresponding studies of Polish youth. Secular changes in the BMI between 1986 and 2016 were significant. Age-adjusted mean BMIs suggested a gradient: 2016 > 2006 > 1996 > 1986. However, changes across the decennial surveys varied. The observed changes in overweight and obesity between 1986 and 2016 were consistent with studies in Poland spanning the past two generations. The age at menarche which were generally consistent with recent surveys of among rural girls in Poland and among girls classified by weight status, however, corresponding comparative data relating menarche to population growth are lacking. Performances of rural school youth on 5 tests of physical fitness changed significantly, but, variably, in the observed period. The results were generally consistent with other studies of Polish school youth that spanned a similar interval. Relationships between the BMI and fitness tests varied across surveys, but suggested reasonably consistent curvilinear relationships between fitness tests and the BMI among boys more so than girls.

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Bartkowiak S, Konarski JM, Strzelczyk R, Janowski J, Malina RM. *Secular change in height and weight of rural school children and youth in west□central Poland: 1986 to 2016.* American Journal of Human Biology, 2021 Mar;33(2):e23461. DOI: 10.1002/ajhb.23461.

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ORIGINAL RESEARCH ARTICLE

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Secular change in height and weight of rural school children and youth in west-central Poland: 1986 to 2016

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Abstract

Objective: To evaluate secular changes in the heights and weights of rural school youth in west-central Poland across decennial surveys of the same communities spanning 1986 and 2016.

Methods: Heights and weights of school youth 7 to 15 years in 10 rural communities in the vicinity of the city of Poznań were measured in 1986 (1417 boys, 1326 girls), 1996 (979 boys, 947 girls), 2006 (871 boys, 843 girls), and 2016 (1189 boys, 1105 girls). Descriptive statistics for sex-specific single year chronological age groups were calculated by survey, while the sample was partitioned into three age groups (7-9, 10-12, 13-15 years) for detailed analysis of changes across surveys using sex-specific ANCOVA with age and age^2 as covariates. Pairwise post hoc comparisons between specific surveys, adjusted for multiple comparisons (Bonferroni), were evaluated.

Results: Heights and weights of rural school youth increased significantly between 1986 and 2016, but estimated secular gains between adjacent surveys were variable and not linear over time.

Conclusion: Significant secular changes occurred in the heights and weights of rural school children in the 10 rural communities between 1986 and 2016, but estimated rates of change across sequential decennial surveys were variable. The results were generally consistent with corresponding studies of Polish youth.

1 | INTRODUCTION

Studies of secular changes in the body size of children, adolescents and young adults over the past 100 years or so have a long tradition, in general (Bielicki, 1986; Malina, 1979, 2004; Roche, 1979; Tanner, 1962, 1981, 1992), and also in Poland (Bielicki & Szklarska, 1999; Jankowiak, 1962; Jasicki, 1938; Łopuszanska-Dawid et al., 2020; Trześniowski, 1990). The Polish data have consistently shown an urban-rural gradient in size attained across time (Hulanicka, Brajczewski, Jedlińska, Sławińska, & Waliszko, 1990; Łaska-Mierzejewska, Dobosz, Nowacka-Dobosz, Olszewska, & Wilczewski, 2016; Nowak, 2012; Przewęda & Dobosz, 2003), although differences between urban and rural children and youth have declined over the past 40 years (Gomuła, Nowak-Szczepańska, Danel, & Kozieł, 2015; Łaska-Mierzejewska et al., 2016; Łaska-Mierzejewska & Olszewska, 2003, 2009; Saczuk, 2018).

Secular changes in Poland have also been addressed in specific urban and rural communities. Heights and weights of urban children and youth resident in the city of Poznań increased across surveys spanning the 1880s and 2000 in boys and the 1920s and 2000 in girls (Krawczyński, Walkowiak, & Krzyżaniak, 2000, 2003). Changes in height between 1990 and 2000, however, were negligible among boys and girls 3 to 18 years;

corresponding changes in weight were also negligible between 3 and 13 years, but boys and girls 14 to 18 years in 1990 were slightly heavier than peers in 2000. Similar trends were noted among urban girls resident in Kraków between 1938 and 2010; changes in height and weight were negligible between 2000 and 2010, except among girls 11 to 16 years who were, on average, slightly heavier in 2010 (Woronkowicz, Cichocka, Kowal, Kryst, & Sobiecki, 2012).

Recent secular gains in heights and weights of rural children and youth in Poland were consistent with those for the general population and for major cities. For example, significant secular gains in the heights and weights of school children and youth resident in towns and villages in several provinces in eastern Poland were noted between 1986 and 2006, but corresponding gains between 2006 and 2016, though significant, were relatively small (Saczuk, 2018). Among school children 7 to 15 years resident in seven rural communities in the copper mining district of Lower Silesia, heights and weights increased significantly between 2000 to 2001 and 2010 to 2011, although weights increased proportionately more than heights (Ignasiak, Sławińska, & Malina, 2016).

The purpose of this study is to compare secular changes in the heights and weights of school children and youth 7 to 15 years of age resident in the same 10 rural communities in the Greater Poland province in west-central Poland across four decennial surveys, 1986, 1996, 2006, and 2016. The time interval spans significant political, economic and social transitions in Poland, which are commonly cited as factors affecting recent secular changes (Gomuła et al., 2015; Saczuk, 2018). The 1986 survey was done during the interval spanning major strikes and political unrest in the early 1980s, the collapse of the communist government, and the first democratic elections in 1991. Subsequent surveys spanned the political, economic and social transitions associated with adaptations to a democratic system. Although community-specific data for the political, economic and social changes are not available, it is reasonable to assume that changes in each community during the interval of the four surveys interacted with and were perhaps differentially influenced by the transitions occurring in country-wide.

2 | METHODS

2.1 | Background

The research was conducted in the Greater Poland province (Wielkapolska voivoidship) located in west-central Poland. The province is second in area (29 826 km^2) and third in population size (~3.5 million in 2017) among the 16 provinces that currently comprise Poland. At the time of the 1986 and 1996 surveys, the communities considered in this study were located in the then Poznań province; in 1999, however, five provinces in the region (Poznań, Kalisz, Konin, Piła, and Leszno) were combined to form Greater Poland (Dziki, 2013).

The city of Poznań is the capital of Greater Poland; other important cities are Kalisz, Konin, Piła, Ostrów Wielkopolski, Gniezno, and Leszno. The province is a major transportation hub, as a great deal of east to west traffic from Russia and other countries formed from the former Soviet Union to Germany and other European Union member states passes through Poznań and Konin. A major highway is currently under construction and will run from the western border of Poland through Poznań to Warsaw, and then via Belarus to Moscow.

A survey of the growth status and physical fitness of children attending schools in 10 rural communities in the province of Poznań was conducted in the 1985/1986 school year (Strzelczyk, 1995). The communities were selected in cooperation with the provincial Board of Education and Development in Poznań and with the approval of the respective community authorities to represent different regions of the province. Available facilities, including a gymnasium (or sports hall) and number of students, were also considered in the selection process. Location of each community relative to the city of Poznań in1986 is shown in Figure 1; distances from the city ranged from 19 km to 75 km, and population sizes varied between 4642 and 9850 in 1986.

School children and youth in the same 10 communities were subsequently surveyed in 1996 (Janowski, 2001; Karpowicz, 2001), 2006 (Janowski, 2017), and 2016 (this

FIGURE 1 Map of the Poznań district and locations of the 10 rural communities in 1986

study). According to local records, none of the 10 communities was involved in previous secular trend research in Poland.

The region comprising the 10 communities had a high proportion of state-owned and cooperative farms at the time of the first survey (Bański, 2010). Two had state-owned farms (Pamiątkowo and Kwilcz), and one had a cooperative farm (Wojnowice). The other communities had family-based farms, but all were located relatively short distances from state farms (4-10 km) and it is likely that some residents worked on the state or cooperative farms. Although rural, one of the communities (Biedrusko) was adjacent to a military base (Baza danych Krajowego Ośrodka Wspierania Rolnictwa, 2019). With the liquidation of state farms in the early 1990s and associated political and economic changes, the structure of agriculture changed with more focus on family owned farms. This is addressed in more detail in the Discussion.

2.2 | Ethics

The initial survey was approved by the provincial Board of Education and Development and educational authorities of each community; the subsequent surveys were approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (KB 907/16 for 2016) and educational authorities of each community. Parents or legal guardians provided written informed consent for their child or children to participate, while the latter provided assent for their participation. The surveys were conducted by faculty and staff of the University of Physical Education in Poznań with the assistance of teachers at each school.

2.3 | Samples

Children and youth comprising the samples were enrolled in elementary schools (grades 1-6) and gymnasiums (grades 7-9) in each community. The total initial sample across all surveys included 4531 boys and 4332 girls (N = 8863), who were classified into single year chronological age (CA) groups with the whole year as the mid-point of the interval, that is, 7 years = 6.50 to 7.49, 8 years = 7.50 to 8.49 ... through ... 15 years = 14.50 to 15.49 years. Seven children were < 6.5 years (3 boys, 4 girls) and 179 were ≥ 15.5 years (75 boys, 104 girls), and were excluded. The latter were represented only in the 2006 and 2016 surveys. The analysis was thus limited to school children and youth 7 to 15 years of age: 1417 boys and 1326 girls in 1986, 979 boys and 947 girls in 1996, 871 boys and 843 girls in 2006, and 1189 boys and 1105 girls in 2016.

2.4 | Anthropometry

Height and weight were measured by trained and experienced staff of the Department of Anthropology and Biometry of the University of Physical Education in Poznań following the procedures of Martin and Saller (1957). Measurements were taken in the gymnasium of each school between 8:00 AM and 3:00 PM; children wore gym clothes (shorts and t-shirt). Height (without shoes) was measured to the nearest millimeter with a Harpenden anthropometer in the four surveys (GPM, Switzerland). Weight was measured to 0.1 kg with a mechanical medical column scale (Lubelskie Fabryki Wag, Poland) in1986, and with electronic weighing scales in the subsequent surveys (Wagi Wielkopolska, Poland, 1996 and 2006 surveys; Tanita, Japan, 2016 survey). The scales were calibrated in the respective communities before each survey.

2.5 | Analysis

Means and standard deviations were calculated for single year CA groups of boys and girls, respectively, in each survey, and the corresponding means were graphically plotted to illustrate trends across time. Given variable numbers across surveys, the samples in each survey were combined into three age groups for more detailed analyses of secular change: (a) 7 to 9 years—middle childhood in both sexes; (b) 10 to 12 years—transition into puberty and mid-puberty (most girls) and transition into puberty (most boys); and (c) 13 to 15 years—late adolescence (most girls), interval of the growth spurt (most boys). Comparisons of height and weight across the four surveys in each of the three age groups were then addressed with sex-specific ANCOVAs with age and age^2 as covariates. Age and age^2 adjust for potential linear and nonlinear effects of age distributions, respectively. Pairwise post hoc comparisons between specific surveys, adjusted for multiple comparisons (Bonferroni), were evaluated. The post hoc comparisons indicate the significance of differences across the 40 year interval and between specific surveys.

3 | RESULTS

3.1 | Trends across surveys

Sample sizes and descriptive statistics for age, height and weight in boys and girls by single year CA groups in each survey are summarized in Table S1, while trends in means across surveys are illustrated in Figures 2 and 3.

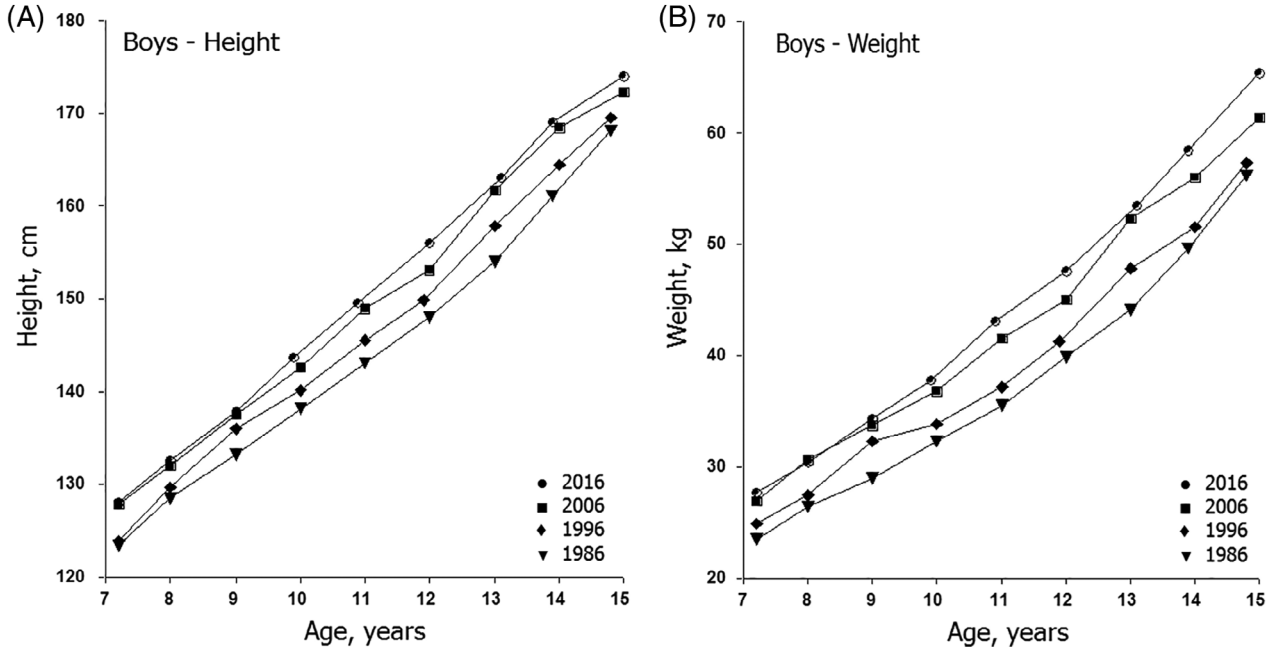

FIGURE 2 Trends in means for A, height and B, weight by CA among boys in the four surveys spanning 1986 through 2016

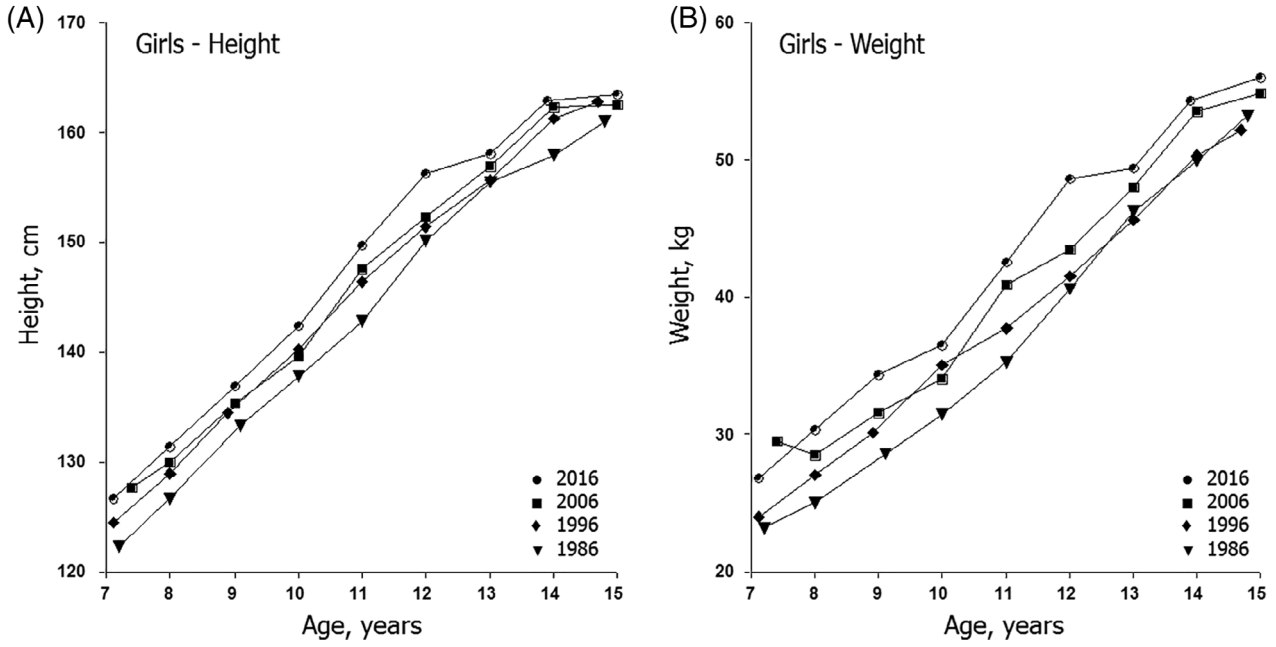

FIGURE 3 Trends in means for A, height and B, weight by CA among girls in the four surveys spanning 1986 through 2016

Among boys (Figure 2A), heights at 7 and 8 years do not differ between 1986 and 1996 and between 2006 and 2016, but heights in the latter are greater at these ages. At subsequent ages, heights systematically increase, on average, across the four surveys. Among girls (Figure 3A), heights in 1996 and 2006 do not consistently differ throughout the age range, allowing for the sample of 7 year old girls in 2006 which was significantly older than samples in the other surveys. Otherwise, heights of girls in 2016 are, on average, taller than those of girls in the other three surveys from 7 through 12 years, while differences are variable between 13 and 15 years.

With few exceptions, the trends in body weight suggest a secular increase across the four surveys of boys (Figure 2B), but the magnitude of differences between 1986 and 1996 and between 2006 and 2016 are relatively

small. Allowing for variation in age among the 7 year old sample in 2006 (noted above), the magnitude of the secular trend in body weight among the four surveys of girls is variable (Figure 3B), although girls in 2016 are, on average, heaviest.

3.2 | Comparisons by age groups

Results of the ANCOVAs in the three combined age groups across the four surveys, controlling for age and age^2, are summarized in Table 1 for boys and Table 2 for girls. Heights and weights differ significantly ($P < .001$) among the four surveys in each age group. Age-adjusted means indicate a reasonably clear gradient across surveys in boys: 2016 > 2006 > 1996 > 1986. Pairwise comparisons between adjacent surveys are significant, except for height in the 7 to 9 and 13 to 15 age groups where 2016 = 2006, and for weight at 7 to 9 years where 2016 = 2006.

The corresponding gradient in age-adjusted mean heights of girls is generally similar in the three age groups: 2016 > 2006 > 1996 > 1986, but pairwise comparisons between specific surveys are not consistent. Height is significantly greater in 2016 than 2006 at 10 to 12 years, but does not differ significantly between the two surveys in girls 7 to 9 and 13 to 15 years. On the other hand, age-adjusted mean heights do not differ significantly between 2006 and 1996 among girls in the three age groups, but heights in 2016 are significantly greater than those in 1996 and 1986 in the three age groups. Although a similar gradient is suggested for body weight among girls, pairwise comparisons across surveys are variable except in children 7 to 9 years, among whom significant pairwise comparisons across surveys indicate a clear secular gradient in body weight: 2016 > 2006 > 1996 > 1986. Among girls 10 to 12 years, age-adjusted mean weights do not differ significantly between 2006 and 1996, but weights in 2016 are significantly greater than those in 1996 and 1986: 2016 > 1996 > 1986. Among girls 13 to 15 years, weights in 1986 and 1996 do not differ, but are significantly less than weights in 2006 and 2016, which do not differ.

3.3 | Estimated decennial changes

Over the 30 year interval, estimated secular changes are similar in boys and girls 7 to 9 years and reasonably similar at 10 to 12 years, while corresponding changes are greater in boys than in girls 13 to 15 years (Table 3). Comparisons of sequential decennial surveys, however, suggest that the secular increases in body size are not linear and variable. Among boys, major gains in height in the three age groups occur between 1996 and 2006 with smaller gains between 1986 and 1996, while estimated gains between 2006 and 2016 are smallest. Major gains in height in girls 7 to 9 and 13 to 15 years occur between 1986 and 1996, followed by relatively similar gains in the subsequent decennial surveys. Among girls 10 to 12 years, the largest secular increase in height occurs between 2006 and 2016 compared to a smaller gain between 1986 and 1996 and a negligible gain between 1996 and 2006.

Gains in body weight between 1996 and 2006 among boys, which increase across the age groups, account for the major portion of observed secular gains over the 40 years spanning 1986-2016. Gains in weight between 1986 and 1996 are smaller and generally similar in the three age groups, while corresponding gains between 2006 and 2016 are minimal at 7 to 9 years and increase in the two older age groups of boys. In contrast, secular gains in weight of girls 7 to 9 and 10 to 12 years are relatively similar across decennial surveys, but gains in girls 13 to 15 years show a major gain between 1996 and 2006 years after no change between 1986 and 1996.

4 | DISCUSSION

Observations for school children and youth resident in 10 rural communities in the vicinity of the city of Poznań between 1986 and 2016 indicated significant secular increases in height and weight over the 30 year interval. However, estimated secular gains between adjacent surveys were variable and not linear over time (Table 3). The heights of rural children and youth 7 to 15 years in the 2016 survey compared favorably to suggested reference data for Poland, while weights were, on average, somewhat higher than the reference (Kułaga et al., 2011). The means heights and weights of youth 10 to 15 years in 2016 compared favorably to youth of the same CA in the Poznań province measured in 2008 to 2011 (Kaczmarek, Cieślik, Hanć, Durda, & Skrzypczak, 2011).

4.1 | Secular changes among polish children and youth

Details of secular changes in studies of Polish children and youth are variably presented in the literature. Some focused primarily on graphic illustration of secular changes, while others were limited to comparisons of adjacent surveys within single year CA groups. Potential age variation within CA groups across time was generally not considered or reported. In the present study of rural

TABLE 1 Means (M) and SD for age, height and weight by survey and age group among boys, results of ANOVA for age and of ANCOVA for height and weight (age, age^2 as covariates), and age-adjusted means (M) and SE

	Year of survey									Year of survey, age-adjusted M, SE								
	1986		1996		2006		2016			1986 (a)		1996 (b)		2006 (c)		2016 (d)		
	M	SD	M	SD	M	SD	M	SD	F	M	SE	M	SE	M	SE	M	SE	Post hoc Comparisons[a]
7-9 y, N	441		272		218		383											
Age, yrs	8.2	0.7	8.2	0.7	8.2	0.8	8.1	0.8	1.73									
Height, cm	129.5	6.8	130.3	7.3	133.3	7.2	133.2	7.4	45.92*	129.2	0.3	130.5	0.3	133.1	0.4	133.5	0.3	$d = c > b > a$
Weight, kg	26.9	5.1	28.5	5.9	31.1	7.7	31.0	7.6	45.16*	26.8	0.3	28.6	0.4	30.9	0.4	31.1	0.3	$d = c > b > a$
10-12 y, N	552		383		376		422											
Age, yrs	11.0	0.8	11.0	0.8	11.0	0.9	10.9	0.9	1.19									
Height, cm	142.9	7.6	145.4	8.5	148.2	8.1	149.5	9.4	88.02*	142.9	0.3	145.0	0.4	148.2	0.4	149.7	0.3	$d > c > b > a$
Weight, kg	35.7	7.3	37.5	9.4	41.0	9.7	42.6	10.3	67.65*	35.7	0.4	37.3	0.4	41.0	0.4	42.8	0.4	$d > c > b > a$
13-15 y, N	454		324		277		384											
Age, yrs	13.8	0.8	13.8	0.7	14.0	0.8	14.0	0.9	9.12*									
Height, cm	160.1	9.8	162.8	9.8	167.3	9.9	168.7	9.4	63.50*	160.6	0.4	163.5	0.5	166.9	0.5	167.8	0.4	$d = c > b > a$
Weight, kg	49.1	10.4	51.2	11.2	56.4	12.3	59.2	13.6	48.82*	49.6	0.5	51.9	0.6	56.0	0.7	58.3	0.6	$d > c > b > a$

*$P < .001$.
[a]Post-hoc comparisons, $P \leq .05$.

TABLE 2 Means (M) and SD for age, height and weight by survey and age group among girls, results of ANOVA for age and of ANCOVA for height and weight (age, age^2 as covariates), and age-adjusted means (M) and SE

	Year of survey									Year of survey, age-adjusted M, SE								
	1986		1996		2006		2016			1986 (a)		1996 (b)		2006 (c)		2016 (d)		
	M	SD	M	SD	M	SD	M	SD	F	M	SE	M	SE	M	SE	M	SE	Post hoc comparisons[a]
7-9 y, N	409		259		219		416											
Age, yrs	8.3	0.8	8.2	0.7	8.4	0.6	8.1	0.8	7.63**									
Height, cm	128.5	6.8	130.1	7.1	132.3	7.0	131.9	7.7	39.47**	128.2	0.3	130.3	0.4	131.5	0.4	132.5	0.3	$d = c, d > b > a, c = b$
Weight, kg	26.1	5.2	27.6	5.6	30.0	6.9	30.7	8.8	46.61**	25.9	0.3	27.7	0.4	29.5	0.4	31.1	0.3	$d > c > b > a$
10-12 y, N	505		377		336		390											
Age, yrs	11.0	0.8	11.0	0.8	11.0	0.8	10.9	0.9	2.07									
Height, cm	143.7	8.4	146.0	8.5	146.3	9.1	149.0	9.3	54.99**	143.4	0.3	145.9	0.4	146.4	0.4	149.5	0.4	$d > c, d > b > a, c = b$
Weight, kg	35.9	8.2	38.1	8.8	39.3	9.8	42.1	11.8	45.30**	35.7	0.4	38.0	0.5	39.4	0.5	42.5	0.5	$d > c, d > b > a, c = b$
13-15 y, N	412		311		288		297											
Age, y	13.7	0.7	13.7	0.7	13.9	0.9	13.9	0.9	4.70*									
Height, cm	157.4	6.5	159.2	7.1	160.4	7.1	161.2	6.7	19.90**	157.5	0.3	159.3	0.4	160.2	0.4	161.1	0.4	$d = c, d > b > a, c = b$
Weight, kg	48.9	8.7	48.7	9.2	51.8	10.1	53.0	10.3	13.07**	49.1	0.5	48.9	0.5	51.6	0.5	52.7	0.5	$d = c > a = b$

*$P < .01$.
**$P < .001$.
[a]Post-hoc comparisons, $P \leq .05$.

TABLE 3 Estimated secular changes in height and weight (means [M] and SE based on ANCOVA with age and age^2 as covariates) between 1986 and 2016 (30 years) and between adjacent decennial surveys in boys and girls

		Secular gains/losses							
		30 years		Adjacent surveys (per decade)					
		1986-2016		1986-1996		1996-2006		2006-2016	
	Age Group	M	SE	M	SE	M	SE	M	SE
Height, cm									
Boys	7-9	4.33	0.41*	1.33	0.45*	2.55	0.53*	0.45	0.49
	10-12	6.86	0.46*	2.15	0.47*	3.14	0.51*	1.57	0.50*
	13-15	7.26	0.58*	2.89	0.60*	3.47	0.68*	0.91	0.65
Girls	7-9	4.34	0.41*	2.11	0.47*	1.17	0.54	1.07	0.50
	10-12	6.10	0.48*	2.52	0.48*	0.49	0.53	3.08	0.53*
	13-15	3.52	0.49*	1.74	0.47*	0.94	0.52	0.84	0.52
Weight, kg									
Boys	7-9	4.39	0.42*	1.85	0.46*	2.28	0.54*	0.26	0.50
	10-12	7.12	0.55*	1.59	0.57*	3.71	0.61*	1.82	0.60*
	13-15	8.67	0.77*	2.31	0.80*	4.04	0.90*	2.31	0.86*
Girls	7-9	5.16	0.45*	1.83	0.51*	1.76	0.59*	1.57	0.55*
	10-12	6.83	0.60*	2.30	0.60*	1.42	0.66	3.11	0.66*
	13-15	3.60	0.70*	−0.23	0.69	2.69	0.75*	1.14	0.76

*$P < .05$.

children and youth from communities in the vicinity of Poznań, secular changes were illustrated graphically (Figures 2 and 3) and were also compared across four decennial surveys in three age groups, 7 to 9, 10 to 12, and 13 to 15 years, statistically controlling for age variation in the different surveys (Tables 1 and 2).

In an effort to integrate the observations for rural school children and youth in the four surveys spanning 1986 through 2016 with studies of secular change in Poland, age-and sex-specific mean heights and weights in each survey and corresponding values reported for children and youth in other surveys of secular change in Poland during approximately the same interval were summarized (Table S2A-D). The studies spanned the age range of the present study, 7 to 15 years, and included two nationally representative samples (Gomuła et al., 2015; Przewęda & Dobosz, 2003), samples from three cities, Poznań (Krawczyński et al., 2000; Krawczyński et al., 2003), Cracow (Kowal et al., 2011) and Rzeszów (Perenc, Radochońska, & Błajda, 2016), and largely rural samples in eastern Poland adjacent to the border with Belarus (Saczuk, 2018; Wilczewski, 2005; Wilczewski & Wilczewski, 2018). All studies used single year CA groups as in the present study with mean ages at the whole year, that is, 7.0, 8.0...15.0 years, except for two studies, one of the national surveys and the surveys in Cracow, which used single year CA groups with mean ages at the mid-year of the interval, that is, 7.5, 8.5...15.5 years.

In addition, estimated secular changes in heights (cm) and weights (kg) across the time intervals considered by each study were expressed as differences between the reported age-specific means in the present study and each comparative study (Table S3A,B). For each study, the differences were initially calculated across the total time interval considered and then calculated between adjacent surveys.

Two key observations were apparent in the studies summarized. First, mean heights and weights of school children and youth resident in rural communities in the region of Poznań in each of the four decennial surveys spanning 1986 and 2016 overlapped those in the other studies of Polish children and youth of the same age, especially those close to the time of each survey. Note, samples in the three national surveys (Przewęda & Dobosz, 2003) and three surveys of Cracow children and youth (Kowal et al., 2011) were, on average, 0.5 year older in each age group than children and youth in the other surveys considered.

Second, mean differences (ie, secular changes) across the total time span of each study/survey overlapped among studies and mean differences between specific pairs of sequential surveys also varied considerably. For example, estimated changes in the heights and weights of each age group of rural boys and girls in the 10 communities between 1986 and 2016 were comparable with and overlapped those noted in national samples between

1988 and 2012 (Gomuła et al., 2015). On the other hand, changes in the heights and weights of each age group of rural boys and girls in the 10 communities between 1986 and 1996 were generally less than corresponding changes in national samples between 1989 and 1999 (Przewęda & Dobosz, 2003). Similar trends were apparent in comparisons with other studies. By inference, secular gains were variable and not linear over time.

4.2 | Transformations in Poland

The secular changes spanning 1986 and 2016 must be viewed within the context major political, economic and social transitions in Poland. As noted earlier, the 1986 survey was done during the interval between major strikes and political unrest in the early 1980s, the collapse of the communist government, and the first democratic elections in 1991. Subsequent surveys spanned significant political, economic and social transitions associated with adaptation to a western democratic system. Although community specific data are not available, it is reasonable to assume that changing and perhaps variable conditions in each community across surveys interacted with the transitions occurring in Poland in general, which contributed to variation in estimated rates of secular change (Table 3).

Changes in the economic and agricultural sectors and their interactions are relevant to discussions of secular change given potential impact on nutritional and health status. Moreover, changes in the agricultural sector are especially relevant given that the communities studied were agriculture-dependent (see below). Although the Polish economy was gradually incorporated into the international and global economic system during interval of the four surveys (Urbanowska-Sojkin & Banaszyk, 2009), it is important to note that the general economy was still largely connected with socialist countries, mainly with the USSR, during the 1986 and 1996 surveys.

The transformation had a major impact on Polish agriculture. In 1980, state farms employed approximately 490 per 1000 individuals, and on average, state farms employed 12 people per 100 ha. More than 50% of state funds allocated to agriculture went to state-owned farms until 1988. Although there were three types of farms in Poland, state, cooperative and family-owned, state farms accumulated large losses through 1993 (Bukraba-Rylska, 2008). The price per unit of products produced by farmers in 1990 to 1991 declined by 63%, while real farm income declined >40% and wages of employees declined by about 37% (Kowalik, 2009). With the shift to a market economy in 1991, state farms were liquidated and assets were taken over by the Agricultural Property Agency of the Treasury (now Agricultural Property Agency).

As noted earlier, the region comprising the 10 rural communities had a high proportion of state-owned and cooperative farms in the 1980s (Bański, 2010). Two communities had state-owned farms (Pamiątkowo and Kwilcz) and one had a cooperative farm (Wojnowice). The others did not have state-owned or cooperative farms, but were located relatively short distances from state farms (4-10 km). It was reasonable to assume that some residents worked on the state-owned or cooperative farms; the communities also had small family-owned farms. One community (Biedrusko) was adjacent to a military base (Baza danych Krajowego Ośrodka Wspierania Rolnictwa, 2019) and likely benefited from jobs associated with the base.

State and cooperative farms also influenced the social life in the rural communities, and in many ways ensured that the needs of employees and their families were met. With the liquidation of state farms in the 1990s and associated political and economic changes, the structure and services of rural communities were also affected. Perhaps the most relevant, among other changes, was the reduction in bus connections and railway lines, and closure of some primary (grades 1-3) and elementary schools (grades 1-6) in the 1990s. Schools in the 10 communities of the present study were not affected by the closures.

The Agricultural Property Agency provided a program for former employees on state farms between 1991 and 2004. The number of unemployment claims indicating state-owned farms as the last place of employment was 100 000 in 1991, but declined by about one-half in 2004 as approximately 48 000 of unemployed individuals received a job or a job offer. In addition, about 1.2 billion Polish złoty were spent on various forms of assistance for those who worked on state farms between 1999 and 2004, including educational scholarships. Former state farm employees were also offered an opportunity to purchase an apartment at preferential rates (Zgliński, 2003).

Access to the European Union in 2004 was important for Polish agriculture as Poland was included with the Common Agricultural Policy (CAP). The policy involved the introduction of direct payments to farmers for their crops and facilitated acquisition of agricultural machinery at reduced prices. On the other hand, the number of small farms which produced food items for personal use was reduced, and the rural population declined during the political and economic transition. The rural population comprised 52% of the national population of Poland in 1960, declined to 41% in 1980 (ie, time of the strikes and political unrest), and was stable through 1990 (38%) and 2016 (40%) (Rocznik Statystyczny Rzeczpospolitej Polskiej, 2017). Nevertheless, changes in rural areas

adjacent to large cities over time contributed to the development of suburban zones which increasingly share features in common with urban centers.

Changes in the 10 communities likely occurred as residents adapted to the new economic conditions. Although family farms were generally more productive during the reforms and many actively joined the developing market economy, alcoholism, passivity and perceptions of helplessness increased in many rural communities as overall agricultural conditions deteriorated (Górecki, 2015; Halamska, 2011). Of relevance, how these changes and others influenced conditions in the specific communities and in turn the growth status of school children in the respective communities across the surveys spanning the 30 year interval merits attention.

The market transformation likely contributed to an improvement in the quality of education in rural areas, and the number of young adult rural residents with a higher education increased over time. Based on questionnaires completed by the parents of children and youth in the four surveys comprising the present study, the majority of parents had only an elementary education in 1986 (~77% of both fathers and mothers). Over the 1996 and 2006 surveys, the proportion of fathers with only an elementary education declined only slightly (75% and 73%, respectively), while the proportion of mothers with only an elementary education declined more so (67% and 57%, respectively). Across the first three surveys, on the other hand, the percentages of mothers with a technical or secondary school education increased steadily, 22%, 29% and 38%, respectively, but the corresponding percentages of fathers changed only slightly, 19%, 19% and 23%, respectively. The proportion of parents of both sexes with a higher education across the first three surveys was 3% in 1986 and 5% in 1996 and 2006, but the educational status of parents of the school children in 2016 changed considerably. Percentages of fathers with an elementary, technical/secondary, or higher education in 2016 were 54%, 30%, and 15%, respectively, while percentages among mothers were 37%, 39%, and 24%, respectively.

Given the economic and political transformations in Poland and associated social, occupational and educational changes, the Polish family and living conditions have changed, especially between 2006 and 2016. Perhaps the most significant was the reduction in multi-generational families and in the number of children in the family. The trends likely reflect the results of the choices of young people who were increasingly investing time in education in an effort to attain a level of education that would provide economic stability, including an increase in the number of working-mothers. The changes undoubtedly influenced responsibilities for child care and after school activities of children (Bieńkowska & Kitlińska-Król, 2017).

4.3 | Overview

The significant changes in political, economic and social conditions in Poland during the interval spanning the four decennial surveys comprising the present study were considerable. Associated changes in living conditions, nutritional status and health care were sufficient to support a significant secular increase in the growth status of rural school children and youth 7 to 15 years of age between 1986 and 2016. Secular increases in the three age groups, 7 to 9, 10 to 12, and 13 to 15 years, however, were not linear across the four decennial surveys. The latter highlighted the need to address secular change in individual communities and to identify community-specific factors that may influence secular changes.

The present study is unique in that school children and youth in the same 10 communities were surveyed on four occasions between 1986 and 2016. Several studies of secular change have also included the same regions and cities (Table S2A-D), though it is not always clear if the same rural communities were considered. Nevertheless, recent studies of secular changes in the BMI in children and youth attending the same schools in urban and rural areas of the Podlaskie Province in 1986 and 2006 (Saczuk & Wasiluk, 2014) and in a random selection of students attending the same schools in the Podcarpathian Province in 1998 and 2008 (Mazur, Klimek, Telega, Filip, & Małecka-Tendera, 2014) have been reported. Unfortunately, the heights and weights of the students were not reported, and variation among communities was not considered.

An indicator of maturity status was not included in the first three surveys. This is a major limitation as it is likely that changes in maturity status across time influenced secular increases in body size. Median age at menarche in girls from the 10 communities, based on the status quo method in the 2016 survey, was 13.3 years (95% CI 13.0-13.7 years), and was slightly later than observed in small cites (13.1, 95% CI 12.9-13.4 years) and rural villages (13.1, 95% CI 12.9-13.3 years) in 2012 (Gomuła & Kozieł, 2018). Of interest, mean ages at menarche among nationally representative samples of Polish girls from urban centers, small cities and rural villages in Poland declined, on average, between 1966 and 1978, increased slightly to 1988, and then declined to 2012 (Gomuła & Kozieł, 2018). Median recalled ages at menarche of rural and urban school girls 13 to 18 years of age in the Greater Poland province based on questionnaire survey in 2009 to 2010 were 13.0 and 12.5 years, respectively (Durda, 2011). The former was comparable to the median age of 13.3 years in the 2016 survey of rural girls.

In summary, the magnitude of the secular changes in the heights and weights of children and youth from 10 rural communities between 1986 and 2016 were

significant and consistent with observations in Poland across this interval. Estimated rates of secular change, however, varied across the four decennial surveys.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Ryszard Strzelczyk, Jarosław Janowski, and Jan M. Konarski were responsible for the 1986, 1996, and 2006 surveys, while Sylwia Bartkowiak was responsible for the 2016 survey. Sylwia Bartkowiak and Jan M. Konarski were responsible for compilation of the data from the four surveys, while Sylwia Bartkowiak, Jan M. Konarski, and Robert M. Malina. were involved in the statistical analyses and preparation of the article. All authors have read and approved the final version of the article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not publicly available due to departmental policy and privacy commitments to the respective communities. Nevertheless, the data may be available on reasonable request to Professor Jan Konarski.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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Supplementary Table 1. Sample sizes and means and standard deviations for age, height and weight in single year chronological age groups by year of survey

	BOYS							GIRLS						
Year, Age Group	N	Age, yrs M	SD	Height, cm M	SD	Weight, kg M	SD	N	Age, yrs M	SD	Height, cm M	SD	Weight, kg M	SD
1986														
7	75	7.2	0.2	123.3	5.0	23.4	3.5	79	7.2	0.2	122.2	5.6	23.1	5.6
8	189	8.0	0.3	128.4	5.9	26.4	5.1	160	8.0	0.3	126.6	5.1	25.0	3.7
9	177	9.0	0.3	133.1	6.0	28.9	4.7	170	9.1	0.3	133.3	5.4	28.6	5.3
10	175	10.0	0.3	138.1	5.8	32.2	5.6	149	10.0	0.3	137.8	5.9	31.4	5.4
11	186	11.0	0.3	143.0	6.2	35.5	6.5	186	11.0	0.3	142.7	7.1	35.2	7.9
12	161	12.0	0.3	148.0	7.5	39.8	7.7	170	12.0	0.3	150.1	7.3	40.6	8.1
13	171	13.0	0.3	153.9	8.4	44.0	9.2	179	13.0	0.3	155.4	6.2	46.2	8.3
14	171	13.9	0.3	161.0	8.1	49.6	9.5	155	14.0	0.3	157.9	6.5	49.9	8.5
15	112	14.8	0.3	168.1	7.4	56.1	9.2	78	14.8	0.2	161.0	5.4	53.2	8.3
1996														
7	64	7.2	0.2	123.7	4.8	24.8	3.7	49	7.1	0.2	124.4	5.9	24.0	3.2
8	115	8.0	0.3	129.6	5.6	27.4	4.1	109	8.0	0.3	128.9	6.2	27.0	5.0
9	93	9.0	0.3	135.9	6.5	32.3	6.8	101	8.9	0.3	134.4	5.9	30.1	6.1
10	114	10.0	0.3	140.1	6.7	33.8	7.5	120	10.0	0.3	140.2	6.6	35.0	8.1
11	137	11.0	0.3	145.5	7.6	37.1	8.0	133	11.0	0.3	146.4	7.1	37.7	7.5
12	132	11.9	0.3	149.8	8.2	41.2	10.8	124	12.0	0.3	151.3	7.9	41.5	9.5
13	128	13.0	0.3	157.8	8.4	47.8	10.5	129	13.0	0.3	155.6	7.6	45.6	9.6
14	130	14.0	0.3	164.4	9.5	51.5	10.8	118	14.0	0.3	161.2	5.3	50.3	8.5
15	66	14.8	0.2	169.5	7.9	57.2	11.0	64	14.7	0.1	162.7	5.8	52.2	7.4

Supplementary Table 1 (continued). Sample sizes and,means and standard deviations for age, height and weight in single year chronological age groups by year of survey

	BOYS							GIRLS						
Year, Age Group	N	Age, yrs M	SD	Height, cm M	SD	Weight, kg M	SD	N	Age, yrs M	SD	Height, cm M	SD	Weight, kg M	SD
2006														
7	48	7.2	0.2	127.7	5.1	26.8	4.6	20	7.4	0.1	127.6	5.1	29.5	6.5
8	79	8.0	0.3	132.0	7.0	30.6	8.0	97	8.0	0.3	130.0	6.1	28.5	5.7
9	91	9.0	0.3	137.4	5.9	33.7	7.7	102	9.0	0.3	135.3	6.8	31.5	7.6
10	123	10.0	0.3	142.6	6.5	36.7	8.1	113	10.0	0.3	139.6	6.9	34.0	7.3
11	128	11.0	0.3	148.9	6.2	41.5	9.1	126	11.0	0.3	147.5	8.6	40.9	9.7
12	125	12.0	0.3	153.0	7.8	44.9	10.0	97	12.0	0.3	152.3	7.0	43.4	9.4
13	92	13.0	0.3	161.6	10.0	52.3	14.1	106	13.0	0.3	156.9	7.0	48.0	10.4
14	103	14.0	0.3	168.4	9.3	55.9	11.0	104	14.0	0.3	162.3	6.1	53.5	9.6
15	82	15.0	0.3	172.3	7.0	61.4	9.8	78	15.0	0.3	162.5	6.5	54.8	8.9
2016														
7	100	7.2	0.2	128.0	6.5	27.6	6.6	123	7.1	0.3	126.6	5.6	26.8	6.2
8	151	8.0	0.3	132.6	6.3	30.3	7.4	146	8.0	0.3	131.4	6.9	30.3	8.3
9	132	9.0	0.3	137.8	6.4	34.3	7.3	147	9.0	0.3	136.8	7.0	34.3	9.7
10	145	9.9	0.3	143.6	7.6	37.8	8.6	140	10.0	0.3	142.4	7.5	36.5	9.7
11	144	10.9	0.3	149.5	8.2	43.0	9.8	137	11.0	0.3	149.7	7.6	42.5	9.9
12	133	12.0	0.3	155.9	8.3	47.5	11.0	113	12.0	0.3	156.2	7.0	48.6	13.0
13	128	13.1	0.3	163.0	9.3	53.4	12.4	111	13.0	0.3	158.0	6.7	49.4	11.1
14	119	13.9	0.3	169.0	8.5	58.4	12.3	96	13.9	0.3	162.9	6.2	54.3	10.0
15	137	15.0	0.3	173.9	6.8	65.3	13.2	90	15.0	0.3	163.4	5.6	56.0	7.9

Supplementary Table 2A. Mean **heights** (cm) of rural BOYS in the present study (1986-2016) and in several studies of secular change in Poland within the time interval

	This	Majority Rural			Urban				Urban
	Study	Eastern Poland		National	Poznań	Rzeszów		National	Cracow
Age	**1986**	**1986**[1]	**1985-6**[2]	**1978**[3]	**1980-1**[4]	**1978-9**[5]	Age	**1979**[6]	**1983**[7]
7	123.3	124.2	124.8	121.7	124.6	121.1	7.5	124.7	124.2
8	128.4	127.6	128.3	127.0	129.3	127.7	8.5	128.8	129.4
9	133.1	132.3	132.7	131.9	134.7	133.1	9.5	133.7	135.0
10	138.1	138.0	137.5	137.1	140.1	137.5	10.5	138.4	140.7
11	143.0	144.9	142.0	141.8	145.2	142.3	11.5	143.3	144.9
12	148.0	147.1	147.1	147.3	150.6	148.6	12.5	148.5	149.2
13	153.9	154.5	153.6	153.0	158.1	155.6	13.5	155.0	157.4
14	161.0	161.8	159.8	160.9	164.3	162.3	14.5	161.8	164.5
15	168.1	165.4	165.8	166.7	172.0	167.8	15.5	167.7	169.8
	1996	**1996**[1]	**1990**[2]	**1988**[3]	**1990-1**[4]	**1993-4**[5]		**1989**[6]	
7	123.7	126.6	122.9	122.2	125.2	121.2	7.5	125.8	
8	129.6	127.4	127.8	128.1	131.3	127.5	8.5	129.6	
9	135.9	133.4	133.0	133.0	135.1	132.9	9.5	134.8	
10	140.1	139.1	137.5	138.3	141.7	137.2	10.5	139.8	
11	145.5	145.0	142.8	142.9	146.5	143.6	11.5	144.4	
12	149.8	150.6	148.2	148.8	152.5	149.0	12.5	150.0	
13	157.8	156.4	154.6	154.7	159.1	154.7	13.5	157.0	
14	164.4	162.8	161.2	162.4	166.5	163.8	14.5	164.4	
15	165.5	169.7	168.9	168.8	172.4	169.6	15.5	170.0	
	2006	**2006**[1]	**2000**[2]		**2000**[4]	**2003-4**[5]		**1999**[6]	**2000**[7]
7	127.7	125.1	124.9		125.5	126.4	7.5	127.8	126.8
8	132.0	130.3	129.5		130.6	130.9	8.5	132.7	132.3
9	137.4	135.3	135.1		135.9	137.3	9.5	137.8	136.6
10	142.6	142.4	139.7		140.8	143.0	10.5	143.2	143.1
11	148.9	146.7	145.1		146.6	146.3	11.5	148.6	149.0
12	153.0	152.2	150.2		152.2	152.7	12.5	155.0	153.6
13	161.6	159.8	157.5		158.8	157.4	13.5	162.1	162.8
14	168.4	166.3	164.8		166.7	165.7	14.5	168.2	168.3
15	172.3	170.2	170.5		171.4	170.9	15.5	173.8	173.7
	2016	**2016**[1]	**2015-6**[2]	**2012**[3]		**2013-4**[5]			**2010**[7]
7	128.0	128.6	128.7	125.2		126.4	7.5		127.7
8	132.6	132.5	133.1	130.5		129.9	8.5		133.8
9	137.8	137.3	137.1	135.9		137.1	9.5		138.6
10	143.6	144.1	144.3	142.2		141.9	10.5		142.9
11	149.5	147.8	148.2	146.5		145.8	11.5		148.9
12	155.9	153.1	153.3	152.9		152.7	12.5		157.0
13	163.0	159.8	158.8	160.0		154.2	13.5		164.7
14	169.0	167.5	167.0	167.4		168.2	14.5		170.1
15	173.9	172.7	173.2	172.8		179.8	15.5		174.2

Supplementary Table 2B. Mean **weights** (kg) of rural BOYS in the present study (1986-2016) and in several studies of secular change in Poland within the time interval

	This	Majority Rural			Urban				Urban
	Study	Eastern Poland		National	Poznań	Rzeszów		National	Cracow
Age	**1986**	**1986**[1]	**1985-6**[2]	**1978**[3]	**1980-1**[4]	**1978-9**[5]	Age	**1979**[6]	**1983**[7]
7	23.4	25.7	24.3	23.5	25.2	24.1	7.5	25.0	25.8
8	26.4	26.7	26.1	25.8	27.5	27.0	8.5	27.1	28.3
9	28.9	30.0	28.8	28.5	30.7	29.9	9.5	29.8	30.7
10	32.2	32.8	31.6	31.6	34.0	32.5	10.5	32.6	34.7
11	35.5	37.9	34.2	34.3	37.7	35.2	11.5	35.7	37.7
12	39.8	38.9	38.2	38.3	41.9	39.3	12.5	39.5	41.3
13	44.0	44.4	43.0	42.9	48.0	45.2	13.5	44.7	47.7
14	49.6	50.7	48.0	48.8	51.9	50.4	14.5	50.5	53.8
15	56.1	58.1	53.1	54.7	59.0	55.1	15.5	56.6	58.9
	1996	**1996**[1]	**1990**[2]	**1988**[3]	**1990-1**[4]	**1993-4**[5]		**1989**[6]	
7	24.8	25.9	23.9	23.7	25.1	23.9	7.5	25.4	
8	27.4	26.6	26.4	26.4	28.3	26.8	8.5	27.3	
9	32.3	29.9	29.3	29.3	31.2	29.5	9.5	30.3	
10	33.8	33.5	31.9	32.5	34.3	32.0	10.5	33.4	
11	37.1	36.6	35.1	35.4	38.5	36.0	11.5	36.6	
12	41.2	40.8	38.8	39.5	43.1	39.4	12.5	40.7	
13	47.8	45.7	44.1	44.4	48.9	44.5	13.5	46.3	
14	51.5	50.3	48.8	50.5	54.4	52.3	14.5	52.9	
15	57.2	54.4	57.1	57.3	61.6	56.8	15.5	59.2	
	2006	**2006**[1]	**2000**[2]		**2000**[4]	**2003-4**[5]		**1999**[6]	**2000**[7]
7	26.8	25.1	24.9		25.5	27.1	7.5	26.4	26.7
8	30.6	27.8	27.1		28.2	30.1	8.5	29.3	29.6
9	33.7	31.5	30.1		31.1	34.1	9.5	32.5	33.5
10	36.7	35.8	33.2		34.3	37.2	10.5	36.1	36.2
11	41.5	38.6	36.6		38.3	39.7	11.5	40.1	40.7
12	44.9	42.9	40.6		42.6	42.3	12.5	45.0	44.2
13	52.3	50.2	45.6		48.0	47.7	13.5	50.5	51.2
14	55.9	56.3	51.3		54.8	54.0	14.5	56.1	54.7
15	61.4	60.4	57.1		59.0	57.9	15.5	62.3	61.8
	2016	**2016**[1]	**2015-6**[2]	**2012**[3]		**2013-4**[5]			**2010**[7]
7	27.6	26.6	26.6	25.4		27.1	7.5		27.0
8	30.3	29.9	29.9	29.4		28.2	8.5		31.5
9	34.3	33.5	33.3	33.2		37.1	9.5		35.3
10	37.8	37.9	38.0	37.3		37.5	10.5		37.3
11	43.0	41.4	41.5	40.6		39.2	11.5		40.9
12	47.5	45.0	45.4	45.3		46.1	12.5		44.8
13	53.4	49.6	50.3	51.9		45.3	13.5		56.3
14	58.4	57.5	58.0	58.0		58.7	14.5		61.4
15	65.3	62.1	63.3	63.6		62.4	15.5		64.5

Supplementary Table 2C. Mean **heights** (cm) of rural GIRLS in the present study (1986-2016) and in several studies of secular change in Poland within the time interval

	This	Majority Rural			Urban				Urban
	Study	Eastern Poland		National	Poznań	Rzeszów		National	Cracow
Age	**1986**	**1986**[1]	**1985-6**[2]	**1978**[3]	**1980-1**[4]	**1978-9**[5]	Age	**1979**[6]	**1983**[7]
7	122.2	124.0	122.9	120.6	123.6	120.7	7.5	123.8	123.5
8	126.6	127.8	126.5	125.8	128.6	125.7	8.5	127.8	128.3
9	133.3	132.1	131.6	130.8	133.6	130.8	9.5	132.9	134.5
10	137.8	137.4	136.4	136.5	139.7	135.9	10.5	138.2	139.2
11	142.7	144.4	142.3	142.3	145.8	143.3	11.5	144.3	145.5
12	150.1	149.2	148.8	149.1	152.5	150.1	12.5	150.3	152.4
13	155.4	154.5	153.8	154.2	157.5	155.8	13.5	155.4	157.3
14	157.9	157.8	158.0	158.2	160.9	159.0	14.5	158.5	160.4
15	161.0	161.1	160.2	159.6	162.7	160.0	15.5	160.2	161.1
	1996	**1996**[1]	**1990**[2]	**1988**[3]	**1990-1**[4]	**1993-4**[5]		**1989**[6]	
7	124.4	123.8	122.5	121.5	124.8	121.7	7.5	124.6	
8	128.9	126.5	126.9	126.7	129.9	126.4	8.5	128.6	
9	134.4	133.1	131.4	132.1	135.5	132.3	9.5	133.7	
10	140.2	138.9	136.8	137.8	140.1	138.0	10.5	139.2	
11	146.4	143.4	142.9	144.3	147.5	143.6	11.5	145.3	
12	151.3	151.5	149.0	150.5	153.9	151.5	12.5	151.7	
13	155.6	156.3	154.9	155.4	158.2	156.2	13.5	156.9	
14	161.2	160.1	158.6	159.9	162.8	159.6	14.5	160.2	
15	162.7	162.6	161.1	161.3	164.4	161.1	15.5	162.1	
	2006	**2006**[1]	**2000**[2]		**2000**[4]	**2003-4**[5]		**1999**[6]	**2000**[7]
7	127.6	124.5	124.2		124.4	123.0	7.5	126.7	126.8
8	130.0	129.6	127.4		129.2	129.3	8.5	131.4	131.8
9	135.3	134.2	133.8		135.0	134.5	9.5	136.8	136.6
10	139.6	141.5	138.7		140.3	139.9	10.5	142.9	143.0
11	147.5	145.8	144.8		147.3	146.1	11.5	149.3	149.3
12	152.3	152.6	151.1		153.0	154.5	12.5	155.8	156.2
13	156.9	158.9	156.9		159.0	158.1	13.5	160.0	160.3
14	162.3	162.3	160.5		162.3	161.9	14.5	162.6	162.7
15	162.5	164.0	162.5		164.1	162.5	15.5	164.0	164.3
	2016	**2016**[1]		**2012**[3]		**2013-4**[5]			**2010**[7]
7	126.6	125.9		124.7		124.4	7.5		125.5
8	131.4	131.2		129.7		129.3	8.5		132.7
9	136.8	135.1		135.2		135.1	9.5		138.1
10	142.4	143.0		141.4		140.9	10.5		143.9
11	149.7	147.5		146.1		143.0	11.5		150.4
12	156.2	153.4		153.5		154.3	12.5		156.7
13	158.0	157.0		159.7		165.2	13.5		160.1
14	162.9	162.2		162.3		164.3	14.5		162.2
15	163.4	165.6		164.4		164.5	15.5		164.5

Supplementary Table 2D. Mean **weights** of (kg) rural GIRLS in the present study (1986-2016) and in several studies of secular change in Poland within the time interval

	This	Majority Rural			Urban				Urban
	Study	Eastern Poland		National	Poznań	Rzeszów		National	Cracow
Age	**1986**	**1986**[1]	**1985-6**[2]	**1978**[3]	**1980-1**[4]	**1978-9**[5]	Age	**1979**[6]	**1983**[7]
7	23.1	25.6	23.5	22.7	24.4	23.5	7.5	24.3	25.2
8	25.0	26.9	25.2	25.0	27.2	25.4	8.5	26.3	27.2
9	28.6	28.4	28.2	27.9	29.8	28.4	9.5	29.0	30.7
10	31.4	32.3	31.4	30.9	33.4	32.0	10.5	32.2	34.7
11	35.2	37.0	34.5	34.8	37.3	35.4	11.5	36.3	37.8
12	40.6	40.1	39.0	39.8	43.2	40.3	12.5	41.1	43.6
13	46.2	44.9	44.7	44.4	48.1	45.8	13.5	46.0	47.8
14	49.9	49.6	48.6	49.6	52.5	50.1	14.5	49.8	52.4
15	53.2	53.2	52.7	51.8	54.8	51.7	15.5	52.8	54.5
	1996	**1996**[1]	**1990**[2]	**1988**[3]	**1990-1**[4]	**1993-4**[5]		**1989**[6]	
7	24.0	24.0	23.9	23.3	24.4	23.9	7.5	24.4	
8	27.0	26.4	25.7	25.3	27.3	25.8	8.5	26.6	
9	30.1	27.7	27.9	28.5	30.3	29.0	9.5	29.4	
10	35.0	32.3	31.6	32.0	33.6	32.6	10.5	32.8	
11	37.7	34.3	35.6	36.2	38.8	35.6	11.5	36.9	
12	41.5	40.9	40.3	41.2	43.7	41.1	12.5	41.9	
13	45.6	45.1	46.0	45.4	49.0	46.1	13.5	46.8	
14	50.3	49.0	50.0	51.1	53.0	50.5	14.5	50.8	
15	52.2	52.9	53.6	53.3	55.7	52.0	15.5	53.5	
	2006	**2006**[1]	**2000**[2]		**2000**[4]	**2003-4**[5]		**1999**[6]	**2000**[7]
7	29.5	24.7	24.4		24.8	25.0	7.5	25.7	25.8
8	28.5	27.1	26.1		27.2	28.0	8.5	28.3	29.3
9	31.5	31.0	29.5		30.3	30.2	9.5	31.5	31.8
10	34.0	34.0	32.9		33.9	33.5	10.5	35.7	35.6
11	40.9	37.0	37.1		38.4	37.0	11.5	40.0	40.8
12	43.4	41.4	41.5		43.2	43.9	12.5	45.3	45.0
13	48.0	48.1	47.2		48.0	48.0	13.5	49.6	49.1
14	53.5	51.4	51.2		52.5	52.3	14.5	52.9	53.1
15	54.8	53.1	54.4		54.1	54.1	15.5	54.9	55.2
	2016	**2016**[1]		**2012**[3]		**2013-4**[5]			**2012**[7]
7	26.8	25.2		25.9		26.6	7.5		25.9
8	30.3	28.7		28.8		32.2	8.5		30.1
9	34.3	31.7		32.0		31.3	9.5		33.2
10	36.5	36.3		36.1		34.7	10.5		37.3
11	42.5	39.8		39.8		39.5	11.5		40.9
12	48.6	43.7		45.3		47.9	12.5		48.1
13	49.4	47.3		51.4		49.0	13.5		52.2
14	54.3	51.6		52.5		51.2	14.5		54.8
15	56.0	55.8		55.3		54.3	15.5		56.7

Sources of comparative data summarized in Supplementary Tables 2A through 2D:

[1]Saczuk (2018), [2]Wilczewski (2005), Wilczewski & Wilczewski (2018), [3]Gomula et al. (2015), [4]Krawczynski et al. (2000, 2003), [5]Perenc et al. (2016), [6] Przewęda & Trześniowski (1996), Przewęda & Dobosz (2003), [7]Chrzanowska, Bocheńska, Panek & Gołąb (1986), Gołąb, Chrzanowska, Żarów, Sobiecki & Brudecki (2002), Kowal, Cichocka, Woronkowicz, Pilecki, Sobiecki, & Kryst (2011)

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The rural-urban samples reported in Saczuk (2018), Wilczewski (2005) and Wilczewski & Wilczewski (2018) were ~55% rural, while the remaining children and youth were from smaller cities in the province and the largest city which was the capital of the province. It should be noted that the current 16 voivoidships (provinces) were established in 1999, while between 1975 and 1998 there were 49 voivoidships. (https://en.wikipedia.org/wiki/Voivodeships_of_Poland accessed 16 September 2019)

The nationally representative data from (Gomula et al., 2015) were from three large cities, Warsaw, Lódz and Wrocław, and from four small towns and villages in four rural districts around the three cities (see Hulanicka et al., 1990).

Supplementary Table 3A. Estimated secular changes in HEIGHT (expressed as differences [cm] between reported age-specific means in each study) across the total interval of each study (bold) and between adjacent surveys spanning the total interval: Estimates for the present study and studies in Poland within the time frame 1996-2016

	BOYS				**GIRLS**			
	Poznań Province, rural, This Study							
Age	**1986-2016**	1986-1996	1996-2006	2006-2016	**1986-2016**	1986-1996	1996-2006	2006-2016
7	**4.7**	0.4	4.0	0.3	**4.4**	2.2	3.2	-0.1
8	**4.2**	1.2	2.4	0.6	**4.8**	2.3	1.1	1.4
9	**4.7**	2.8	1.5	0.4	**3.5**	1.1	0.9	1.5
10	**5.5**	2.0	2.5	1.0	**4.6**	2.4	-0.6	2.8
11	**6.5**	2.5	3.4	0.6	**7.0**	3.7	1.1	2.2
12	**7.9**	1.8	3.2	2.9	**6.1**	1.2	1.0	3.9
13	**9.1**	3.9	3.8	1.4	**2.6**	3.3	1.1	0.6
14	**8.0**	3.4	4.0	0.6	**5.0**	3.3	1.1	0.6
15	**5.8**	-2.6	6.8	1.6	**2.4**	1.7	-0.2	0.9

	BOYS				**GIRLS**			
	Eastern Poland, largely rural (Saczuk, 2015)							
Age	**1986-2016**	1986-1996	1996-2006	2006-2016	**1986-2016**	1986-1996	1996-2006	2006-2016
7	**4.4**	2.4	-1.5	3.5	**1.9**	-0.2	0.7	1.4
8	**4.9**	-0.2	2.9	2.2	**3.4**	-1.3	3.1	1.6
9	**5.0**	1.1	1.9	2.0	**3.0**	1.0	1.1	0.9
10	**6.1**	1.1	3.3	1.7	**5.6**	1.5	2.6	1.5
11	**2.9**	0.1	1.7	1.1	**3.1**	-1.0	2.4	1.7
12	**6.0**	3.5	1.6	0.9	**4.2**	2.3	1.1	0.8
13	**5.3**	1.9	3.4	0.0	**2.5**	1.8	2.6	-1.9
14	**5.7**	1.0	3.5	1.2	**4.4**	2.3	2.2	-0.1
15	**7.3**	4.3	0.5	2.5	**4.5**	1.5	1.4	1.6

	Eastern Poland, largely rural (Wilczewski, 2005; Wilczewski & Wilczewski, 2018						
Age	**1985-2015**	1985-1990	1990-2000	2000-2015	**1985-2016**	1985-1990	1990-2000
7	**3.9**	-1.9	2.0	3.8	**1.3**	-0.4	1.7
8	**4.8**	-0.5	1.7	3.6	**0.9**	0.4	0.5
9	**4.4**	0.3	2.1	2.0	**2.2**	-0.2	2.4
10	**6.8**	0.0	2.2	4.6	**2.3**	0.4	1.9
11	**6.2**	0.8	2.3	3.1	**2.5**	0.6	1.9
12	**6.2**	1.1	2.0	3.1	**2.3**	0.2	2.1
13	**5.2**	1.0	2.9	1.3	**3.1**	1.1	2.0
14	**7.2**	1.4	3.6	2.2	**2.5**	0.6	1.9
15	**7.4**	3.1	1.6	2.7	**2.3**	0.9	1.4

	Rzeszow Eastern Poland urban (Perenc et al., 2016)							
Age	**1978-2013**	1978-1993	1993-2003	2003-2013	**1978-2013**	1978-1993	1993-2003	2003-2013
7	**5.3**	0.1	5.2	0.0	**3.7**	1.0	1.3	1.4
8	**2.2**	-0.2	3.4	-1.0	**3.6**	0.7	2.9	0.0
9	**4.0**	-0.2	4.4	-0.2	**4.3**	1.5	2.2	0.6
10	**4.4**	-0.3	5.8	-1.1	**5.0**	2.1	1.9	1.0
11	**3.5**	1.3	2.7	-0.5	**-0.3**	0.3	2.5	-3.1
12	**4.1**	0.4	3.7	0.0	**4.2**	1.4	3.0	-0.2
13	**-1.4**	-0.9	2.7	-3.2	**9.4**	0.4	1.9	7.1
14	**5.9**	1.5	1.9	2.5	**5.3**	0.6	2.3	2.4
15	**12.0**	1.8	1.3	8.9	**4.5**	1.1	1.4	2.0

	BOYS			GIRLS		
	Poznań urban (Krawczynski et al., 2000, 2003)					
Age	**1980-2000**	1980-1990	1990-2000	**1980-2000**	1980-1990	1990-2000
7	**0.9**	0.6	0.3	**0.8**	1.2	-0.4
8	**1.3**	2.0	-0.7	**0.6**	1.3	-0.7
9	**1.2**	0.4	0.8	**1.4**	1.9	-0.5
10	**0.7**	1.6	-0.9	**0.6**	0.4	0.2
11	**1.4**	1.3	0.1	**1.5**	1.7	-0.2
12	**1.6**	1.9	-0.3	**0.5**	1.4	-0.9
13	**0.7**	1.0	-0.3	**1.5**	0.7	0.8
14	**2.4**	2.2	0.2	**1.4**	1.9	-0.5
15	**-0.6**	0.4	-1.0	**1.4**	1.7	-0.3

	BOYS			GIRLS		
	Cracow urban* (Chrzanowska et al., 1986; Goląb et al., 2002; Kowal et al., 2011)					
Age	**1983-2010**	1983-2000	2000-2010	**1983-2010**	1983-2000	2000-2010
7	**3.5**	2.6	0.9	**2.0**	3.3	-1.3
8	**4.4**	2.9	1.5	**4.4**	3.5	0.9
9	**3.6**	1.6	2.0	**3.6**	2.1	1.5
10	**2.2**	2.4	-0.2	**4.7**	3.8	0.9
11	**4.0**	4.1	-0.1	**4.9**	3.8	1.1
12	**7.8**	4.4	3.4	**4.3**	3.8	0.5
13	**7.3**	5.4	1.9	**2.8**	3.0	-0.2
14	**5.6**	3.8	1.8	**1.8**	2.3	-0.5
15	**4.4**	3.9	0.5	**3.4**	3.2	0.2

	BOYS			GIRLS		
	National* (Przewęda & Trześniowski, 1996; Przewęda & Dobosz, 2003)					
Age	**1979-1999**	1979-1989	1989-1999	**1979-1999**	1979-1989	1989-1999
7	**2.9**	1.0	2.0	**2.9**	0.8	2.1
8	**3.9**	0.8	3.1	**3.6**	0.8	2.8
9	**4.2**	1.1	3.1	**3.9**	0.8	3.0
10	**4.7**	1.3	3.4	**4.7**	1.0	3.7
11	**5.3**	1.0	4.3	**5.1**	1.1	4.0
12	**6.4**	1.4	5.0	**5.5**	1.4	4.1
13	**7.1**	1.9	5.2	**4.7**	1.5	3.2
14	**6.4**	2.5	3.9	**4.2**	1.8	2.4
15	**6.2**	2.4	3.8	**3.8**	1.9	1.9

	BOYS			GIRLS		
	National (Gomula et al., 2015)					
Age	**1978-2012**	1978-1988	1988-2012	**1978-2012**	1978-1988	1988-2012
7	**3.5**	0.5	3.0	**4.1**	0.9	3.2
8	**3.5**	1.1	2.4	**3.9**	0.9	3.0
9	**4.0**	1.1	2.9	**4.4**	1.3	3.1
10	**5.1**	1.2	3.9	**4.9**	1.3	3.6
11	**4.7**	1.1	3.6	**3.8**	2.0	1.8
12	**5.6**	1.5	4.1	**4.4**	1.4	3.0
13	**7.0**	1.7	5.3	**5.5**	1.2	4.3
14	**6.5**	1.5	5.0	**4.1**	1.7	2.4
15	**6.1**	2.1	4.0	**4.8**	1.7	3.1

*Age groups reported as the mid-year of the interval, i.e., 7 = 7.0 to 7.99 years (7.5). In all other studies, age groups are reported with the whole year as the midpoint of the interval, i.e., 7 = 6.5 to 7.49 years (7.0).

Supplementary Table 3B. Estimated secular changes in WEIGHT (expressed as differences [kg] between reported age-specific means in each study) across the total interval of each study (bold) and between adjacent surveys spanning the total interval: Estimates for the present study and studies in Poland within the time frame 1996-2016

	BOYS				**GIRLS**			
	Poznań Province, rural, This Study							
Age	**1986-2016**	1986-1996	1996-2006	2006-2016	**1986-2016**	1986-1996	1996-2006	2006-2016
7	**4.2**	1.4	2.0	0.8	**3.7**	0.9	5.5	-2.7
8	**3.9**	1.0	3.2	-0.3	**5.3**	2.0	1.5	1.8
9	**5.4**	3.4	1.4	0.6	**5.7**	1.5	1.4	2.8
10	**5.6**	1.6	2.9	1.1	**5.1**	3.6	-1.0	2.5
11	**7.5**	1.6	4.4	1.5	**7.3**	2.5	3.2	1.6
12	**7.7**	1.4	3.7	2.6	**8.0**	0.9	1.9	5.2
13	**9.4**	3.8	4.5	1.1	**3.2**	-0.6	2.4	1.4
14	**8.8**	1.9	4.4	2.5	**4.4**	0.4	3.2	0.8
15	**9.2**	1.1	4.2	3.9	**2.8**	-1.0	2.6	1.2

	BOYS				**GIRLS**			
	Eastern Poland, largely rural (Saczuk, 2015)							
Age	**1986-2016**	1986-1996	1996-2006	2006-2016	**1986-2016**	1986-1996	1996-2006	2006-2016
7	**0.9**	0.2	-0.8	1.5	**-0.4**	-1.6	0.7	0.5
8	**3.2**	-0.1	1.2	2.1	**1.8**	-0.5	0.7	1.6
9	**3.5**	-0.1	1.6	2.0	**3.3**	-0.7	3.3	0.7
10	**5.1**	0.7	2.3	2.1	**4.0**	0.0	1.7	2.3
11	**3.5**	-1.3	2.0	2.8	**2.8**	-2.7	2.7	2.8
12	**6.1**	1.9	2.1	2.1	**3.6**	0.8	0.5	2.3
13	**5.2**	1.3	4.5	-0.6	**2.4**	0.2	3.0	-0.8
14	**6.8**	-0.4	6.0	1.2	**2.0**	-0.6	2.4	0.2
15	**4.0**	-3.7	6.0	1.7	**2.6**	-0.3	0.2	2.7

	Eastern Poland, largely rural (Wilczewski, 2005; Wilczewski & Wilczewski, 2018						
Age	**1985-2015**	1985-1990	1990-2000	2000-2015	**1985-2016**	1985-1990	1990-2000
7	**2.3**	-0.4	1.0	1.7	**0.9**	0.4	0.5
8	**3.8**	0.3	0.7	2.8	**0.9**	0.5	0.4
9	**4.5**	0.5	0.8	3.2	**1.3**	-0.3	1.6
10	**6.4**	0.3	1.3	4.8	**1.5**	0.2	1.3
11	**7.3**	0.9	1.5	4.9	**2.6**	1.1	1.5
12	**7.2**	0.6	1.8	4.8	**2.5**	1.3	1.2
13	**7.3**	1.1	1.5	4.7	**2.5**	1.3	1.2
14	**10.0**	0.8	2.5	6.7	**2.6**	1.4	1.2
15	**10.2**	4.0	0.0	6.2	**1.7**	0.9	0.8

	Rzeszow Eastern Poland urban (Perenc et al., 2016)						
	1978-2013	1978-1993	1993-2003	2003-2013	**1978-2013**	1978-1993	1993-2003	2003-2013
	3.0	-0.2	3.2	0.0	**3.1**	0.4	1.1	1.6
	1.2	-0.2	3.3	-1.9	**6.8**	0.4	2.2	4.2
	7.2	-0.4	4.6	3.0	**2.9**	0.6	1.2	1.1
	5.0	-0.5	5.2	0.3	**2.7**	0.6	0.9	1.2
	4.0	0.8	3.7	-0.5	**4.1**	0.2	1.4	2.5
	6.8	0.1	2.9	3.8	**7.6**	0.8	2.8	4.0
	0.1	-0.7	3.2	-2.4	**3.2**	0.3	1.9	1.0
	8.3	1.9	1.7	4.7	**1.1**	0.4	1.8	-1.1
	7.3	1.7	1.1	4.5	**2.6**	0.3	2.1	0.2

	BOYS			GIRLS		
	Poznań urban (Krawczynski et al., 2000, 2003)					
Age	**1980-2000**	1980-1990	1990-2000	**1980-2000**	1980-1990	1990-2000
7	**0.3**	-0.1	0.4	**0.4**	0.0	0.4
8	**0.7**	0.8	-0.1	**0.0**	0.1	-0.1
9	**0.4**	0.5	0.1	**0.5**	0.5	0.0
10	**0.3**	0.3	0.0	**0.5**	0.2	0.3
11	**0.6**	0.8	-0.2	**1.1**	1.5	-0.4
12	**0.7**	1.2	-0.5	**0.0**	0.5	-0.5
13	**0.0**	0.9	-0.9	**-0.1**	0.9	-1.0
14	**2.9**	2.5	0.4	**0.0**	0.5	-0.5
15	**0.0**	2.6	-2.6	**-0.7**	0.9	-1.6

	BOYS			GIRLS		
	Cracow urban* (Chrzanowska et al., 1986; Goląb et al., 2002; Kowal et al., 2011)					
Age	**1983-2010**	1983-2000	2000-2010	**1983-2010**	1983-2000	2000-2010
7	**1.2**	0.9	0.3	**0.7**	0.6	0.1
8	**3.2**	1.3	1.9	**2.9**	2.1	0.8
9	**4.6**	2.8	1.8	**2.5**	1.1	1.4
10	**2.6**	1.5	1.1	**2.6**	0.9	1.7
11	**3.2**	3.0	0.2	**3.1**	3.0	0.1
12	**3.5**	2.9	0.6	**4.5**	1.4	3.1
13	**8.9**	3.8	5.1	**4.4**	1.3	3.1
14	**7.6**	0.9	6.7	**2.4**	0.7	1.7
15	**5.6**	2.9	2.7	**2.2**	0.7	1.5

	National* (Przewęda & Trześniowski, 1996; Przewęda & Dobosz, 2003)					
Age	**1979-1999**	1979-1989	1989-1999	**1979-1999**	1979-1989	1989-1999
7	**1.4**	0.4	1.0	**1.4**	0.1	1.3
8	**2.2**	0.2	2.0	**2.0**	0.3	1.7
9	**2.8**	0.5	2.3	**2.5**	0.4	2.1
10	**3.5**	0.8	2.7	**3.5**	0.6	2.9
11	**4.3**	0.8	3.5	**3.7**	0.6	3.1
12	**5.4**	1.1	4.3	**4.2**	0.8	3.4
13	**5.8**	1.5	4.3	**3.6**	0.8	2.8
14	**5.6**	2.3	3.3	**3.0**	1.0	2.0
15	**5.7**	2.6	3.1	**2.1**	0.7	1.4

	National (Gomula et al., 2015)					
Age	**1978-2012**	1978-1988	1988-2012	**1978-2012**	1978-1988	1988-2012
7	**1.9**	0.2	1.7	**3.2**	0.6	2.6
8	**3.6**	0.6	3.0	**3.8**	0.3	3.5
9	**4.7**	0.8	3.9	**4.1**	0.6	3.5
10	**5.7**	0.9	4.8	**5.2**	1.1	4.1
11	**6.3**	1.1	5.2	**5.0**	1.4	3.6
12	**7.0**	1.2	5.8	**5.5**	1.4	4.1
13	**9.0**	1.5	7.5	**7.0**	1.0	6.0
14	**9.2**	1.7	7.5	**2.9**	1.5	1.4
15	**8.9**	2.6	6.3	**3.5**	1.5	2.0

*Age groups reported as the mid-year of the interval, i.e., 7 = 7.0 to 7.99 years (7.5). In all other studies, age groups are reported with the whole year as the midpoint of the interval, i.e., 7 = 6.5 to 7.49 years (7.0).

Note: References cited are as indicated in Supplementary Tables 2A through 2D

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Article

Weight status of rural school youth in Poland: secular change 1986–2016

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With 2 figures and 3 tables

Abstract: The objective of this study was to evaluate secular changes in the Body Mass Index (BMI) and weight status of rural children and adolescents in west-central Poland across decennial surveys spanning 1986 and 2016. Participants were 8,677 boys and girls 7–15 years attending schools in 10 rural communities in 1986, 1996, 2006, and 2016. Heights and weights were measured; BMIs were calculated. Weight status was classified using International Obesity Task Force (IOTF) criteria. The sample was partitioned into three age groups (7–9, 10–12, 13–15 years) for analysis of secular change in the BMI using sex-specific analysis of covariance (ANCOVA) with age and age^2 as covariates, and for comparison of the prevalence of mild, moderate and severe thinness and of overweight and obesity. BMIs increased, on average, across the four surveys, but differences between adjacent surveys varied. Prevalence of severe and moderate thinness was low in both sexes, while mild thinness tended to decline over time, more so among girls. Overweight and obesity increased over time, especially in 2006 and 2016 compared to 1986 and 1996. In conclusion, secular changes in the BMI between 1986 and 2016 were significant. Age-adjusted mean BMIs suggested a gradient, 2016 > 2006 > 1996 > 1986, except in girls 13–15 years. However, changes across the decennial surveys varied. The observed changes in overweight and obesity between 1986 and 2016 were consistent with studies in Poland spanning the past two generations.

Keywords: thinness; overweight; obesity; children; adolescents; Europe

1 Introduction

The increasing prevalence of overweight (OWT) and obesity (OB), defined by the body mass index (BMI, kg/m^2) among children and adolescents is a major public health concern. Using International Obesity Task Force (IOTF) criteria (Cole et al. 2000), the age-standardized prevalence of OWT and OB among youth < 20 years in developed countries between 1980 and 2013, increased from ~17% to 24% in boys and ~16% to 23% in girls; in lesser developed countries, the prevalence increased from 8% to 13% in both sexes (Ng et al. 2014). The age-standardized estimates for OWT and OB among youth < 20 years Poland in 2013 were, respectively, 22% and 7% of boys and 18% and 6% of girls (Ng et al. 2014).

A more recent review limited to children 7–13 years suggested that the prevalence of OWT and OB, though high, stabilized in most European countries (Garrido-Miguel et al. 2019). Among youth 7–13 years in Central European countries, the estimated prevalence of OWT was 16% in 1999–2006, 19% in 2007–2010 and 18% in 2011–2016; the prevalence of OB was, respectively, 2.7%, 5.5% and 3.2% (Garrido-Miguel et al. 2019).

Changes in lifestyle, specifically the adoption of Western diets and reduced physical activity, are often indicated as

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primary factors associated with the increasing prevalence of OWT and OB among children and adolescents in many countries, especially those undergoing rapid development (Lobstein et al. 2004; Hu 2011). Reduced physical activity is often linked to increased sedentary behavior, although the two are independent behaviors.

While current discussions focus on OWT and OB, low weight-for-height, labeled underweight or thinness, persists in some areas of the world or segments of the population. Based on pooled data for children and adolescents 5–19 years and World Health Organization (WHO 1995) criteria (de Onis et al. 2007; de Onis & Lobstein 2010), the age-standardized global prevalence of moderate and severe thinness between 1975 and 2016 changed slightly in both sexes, 15% to 12% in boys and 9% to 8% in girls, while the global prevalence of OB was < 1% in 1975 and increased, respectively, to 8% and 6% in boys and girls in 2016 (NCD Risk Factor Collaboration 2017). Using IOTF criteria for thinness (Cole et al. 2007), the prevalence of severe, moderate and mild thinness among adolescents 13–18 years in west-central Poland in 2009–2010 was, respectively, 0.6%, 1.7% and 8.6% in girls and 0.2%, 1.1% and 6.7% in boys (Durda 2011).

Secular changes in the BMI and/or prevalence of OWT and OB among children and adolescents in Poland have been addressed in national (Gomuła et al. 2015) and regional (Chrzanowska et al. 2007; Mazur et al. 2014; Saczuk & Wasiluk 2014; Perenc et al. 2016) samples. Studies spanned 1966 through 2014. Allowing for variation in intervals considered, the overall trends suggested an increase in OWT more so than in OB between 1966 and 2014. Only one study considered thinness and noted small changes between 1986 and 2006 (Saczuk & Wasiluk 2014).

Two of the surveys in Poland included rural and urban children and adolescents, but the samples were combined for the respective analyses (Mazur et al. 2014; Saczuk & Wasiluk 2014). Of relevance, some studies indicate higher levels of obesity among rural children compared to urban peers and the general population (Chwałczyńska et al. 2018). Underlying factors may reflect a lower standard of living compared to urban areas, lack of access to health care, reduced awareness, and/or limited options for free time activities. Some data indicate lower levels of physical activity among rural children (Hedley et al. 2004; Paxton et al. 2004; Durda 2011).

Long-term observations on children and adolescents for rural areas in the Greater Poland region (Wielkopolska) are lacking. The purpose of this study is to evaluate secular changes in the BMI and weight status (thinness, OWT and OB) of rural school children and adolescents 7–15 years in west-central Poland across four decennial surveys, 1986, 1996, 2006 and 2016. The students were resident in and attended schools in the same ten communities at the time of each survey. The study addressed two questions: Are there changes in the weight status of rural children and adolescents resident in the Wielkopolska region? If so, what is the direction and magnitude of the changes in boys and girls? Given data available for Poland and trends worldwide, it was hypothesized that the BMI and in turn OWT and OB status would increase between 1986 and 2016.

2 Methods

2.1 Background

The growth status and physical fitness of children and adolescents in ten rural communities in the province of Poznań were evaluated in the 1985/1986 school year (Strzelczyk, 1995). The communities were selected to represent different regions of the province with the assistance of the provincial Board of Education and Development in Poznań and approval of the respective community authorities. Schools were selected for study in 1985/1986 on the basis of the number of enrolled students and facilities, specifically a gymnasium or sports hall for measurement and fitness testing. Subsequent surveys of students in the same schools were conducted in 1996 (Janowski 2001; Karpowicz 2001), 2006 (Janowski 2017), and 2016 (Bartkowiak et al. 2021a; Bartkowiak et al. 2021b). Distances of the communities from the city of Poznań ranged from 19 to 75 km, and population sizes in 1986 varied between 4642 and 9850. Distance from Poznan and population size in 1986 highlight the relative homogeneity of the total sample, and provide a baseline for evaluation of changes in the regions over time.

The 1986 survey was done during the interval spanning major strikes and political unrest in Poland in the early 1980s, the collapse of the communist government, and the first democratic elections in 1991. Subsequent surveys were done during the political, economic and social transitions associated with adaptations to a democratic system. It is reasonable to assume that conditions in each community during the interval of the four surveys interacted with and were influenced by the transitions occurring in country-wide, although community-specific data are not available.

2.2 Ethics

The initial survey was approved by the provincial Board of Education and Development and educational authorities of each community following regulations that were in effect at the time. The subsequent surveys were approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (KB 907/16 for 2016) and educational authorities of each community. Parents or legal guardians provided written informed consent for their child/children to participate; children provided assent for their participation. Surveys were conducted by faculty and staff of the University of Physical Education in Poznań with the assistance of teachers at each school.

2.3 Sample

The sample included 8,677children and adolescents 7–15 years: 1,417 boys and 1,326 girls in 1986, 979 boys and 947 girls in 1996, 871 boys and 843 girls in 2006, and 1,189 boys and 1,105 girls in 2016. The samples represent all of the students in the respective schools for whom written permission from parents or legal guardians was provided. Children with medical contraindications noted by parents and/or school officials/nurses were excluded Single year chronological age (CA) groups were formed so that the whole year was the mid-point of the interval (7 years = 6.50 to 7.49, etc.).

2.4 Anthropometry and weight status

Height and weight were measured during the school day between 8:00 AM and 3:00 PM by experienced staff of the Department of Anthropology and Biometry of the Poznań University of Physical Education. Height (without shoes) was measured to the nearest millimeter (0.1 cm) with a Harpenden anthropometer in the four surveys (GPM, Switzerland). Weight was measured to 0.1 kg with a mechanical medical column scale in 1986 (Lubelskie Fabryki Wag, Poland) and with electronic weighing scales in the subsequent surveys (Wagi Wielkopolska, Poland, 1996 and 2006; Tanita, Japan, 2016). The scales were calibrated in the respective schools before each survey (Bartkowiak et al. 2021a). The BMI was calculated (kg/m^2) and used to classify the weight status of each student as severely, moderately or mildly thin, normal, OWT or OB using age- and sex-specific IOTF cut-offs (Cole et al. 2000; Cole et al. 2007). The criteria include whole year and half-year CA intervals, e.g., 7.0, 7.5, etc. (Cole et al. 2007).

2.5 Analysis

Preliminary sex-specific analyses indicated inconsistent differences in BMIs and distributions by weight status within and between surveys in the ten communities. Data for communities within each decennial survey were thus combined for analysis of secular change in the BMI and weight status across surveys. Descriptive statistics (means, standard deviations and medians) for the total samples in each survey were calculated for the BMI in single year chronological age (CA) groups of boys and girls; survey-specific medians were graphically plotted by sex.

To allow for variation in numbers of subjects within single year CA groups, the samples in each survey were combined into three composite CA groups for more detailed analyses: [1] 7–9 years – middle childhood in both sexes; [2] 10–12 years – transition into puberty and mid-puberty for most girls and transition into puberty for most boys; and [3] 13–15 years – later adolescence for most girls and the interval of the growth spurt for most boys. The groups approximated developmental stages commonly used in studies of school children and adolescents (Malina et al. 2004). BMIs across surveys within each of the three age groups were compared with sex-specific analyses of covariance (ANCOVAs) with CA and CA^2 as covariates. The latter adjusts for potential linear and non-linear effects of CA distributions, respectively. Post hoc comparisons between specific surveys, adjusted for multiple comparisons (Bonferroni), were evaluated. The prevalence of mild, moderate and severe thinness and of OWT and OB was also calculated for the three combined CA groups of boys and girls in each survey. All analyses were done with SPSS for Windows (version 22.0, IBM SPSS, Chicago, IL).

3 Results

3.1 BMI trends across surveys

Sample sizes and descriptive statistics for the BMI in single year CA groups in each survey are summarized in Supplementary Tables 1 (boys) and 2 (girls), while trends in medians by CA across surveys are illustrated in Fig. 1. The median for girls 7 years in the 2006 survey is not shown;

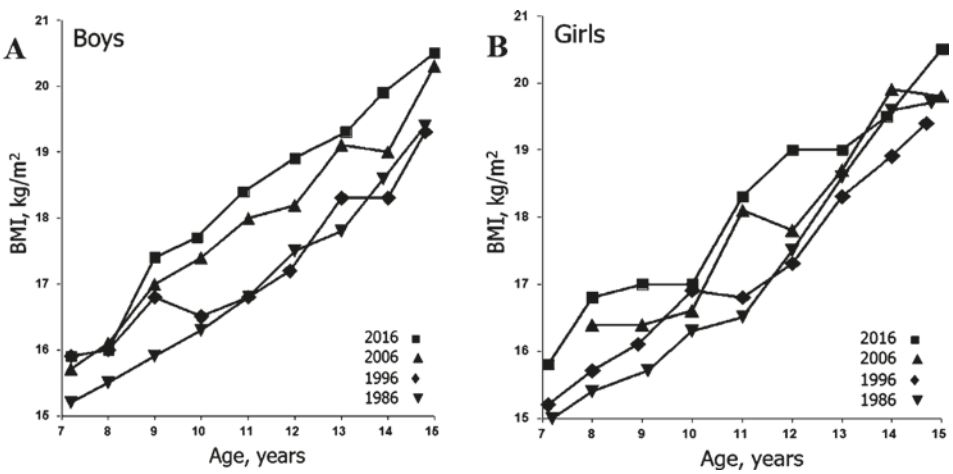

Fig. 1. Median BMIs by age in the four surveys of rural boys **(A)** and girls **(B)**.

the small sample had a mean CA significantly older than the other surveys.

The trends indicate a secular increase in the BMI across surveys in both boys and girls. The major contrast among boys (Fig. 1A) is between 1986 and 2016, while contrasts vary between adjacent surveys. Median BMIs of boys 10–15 years in 1986 and 1996 differ negligibly. Median BMIs are slightly higher among boys in 2016 than 2006 between 9 and 12 years, while differences are variable between 13 and 15 years. Median BMIs of girls (Fig. 1B) vary considerably across surveys and with age. Prior to 13 years, BMIs in 2016 are higher than in 1996 and 1986, but the age trend in 2006 is variable. Among girls 13–15 years, BMIs are lowest in 1996, but overlap considerably among the other surveys.

3.2 BMI ANCOVAs across surveys

Results of the sex-specific ANCOVAs across the four surveys in each of the three age groups are summarized in Table 1. Overall, BMIs differ significantly ($p < 0.001$) between 1986 and 2016 in each CA group of both boys and girls; estimates of effect size (η_p^2) approximate moderate levels except among girls 13–15 years. However, trends across the four surveys are variable.

Age-adjusted mean BMIs among boys suggest a gradient, 2016 > 2006 > 1996 > 1986, but the significance of comparisons vary between specific surveys. In each age group, BMIs in 2016 and 2006 do not differ, and both are significantly higher than BMIs in 1996 and 1986 except among boys 7–9 in whom the BMI in 1996 is significantly greater than in 1986.

Among girls 7–9 and 10–12 years, age-adjusted BMIs show a similar gradient across surveys as in boys, but the post hoc comparisons are more variable. Among girls 7–9 years, BMIs do not differ between 1986 and 1996, but are significantly lower compared to 2006 and 2016 which do not differ. Among girls 10–12 years, BMIs in 2016 and 2006 do not differ, but are significantly greater than the BMI in 1986; BMIs in 2006, however, do not differ from those in 1996. Among girls 13–15 years, in contrast, only two post hoc comparisons are significant; BMIs in 2016 and 2006 are significantly greater than in 1996.

Table 1. Means and standard deviations for age and the BMI in the boys and girls in each age group by year of survey, results of ANOVA (age) and ANCOVA (BMI with age and age^2 as covariates) and effect sizes (η_p^2), and age-adjusted means and standard errors and significant post hoc comparisons.

	Year of survey								F	η_p^2	Year of survey, age-adjusted M, SE								Significant post hoc comparisons†
	1986		1996		2006		2016				1986 (a)		1996 (b)		2006 (c)		2016 (d)		
	M	SD	M	SD	M	SD	M	SD			M	SD	M	SD	M	SD	M	SD	
Boys																			
7–9 yrs, N	441		272		218		383												
Age, yrs	8.2	0.7	8.2	0.7	8.2	0.8	8.1	0.8	1.73										
BMI, kg/m^2	15.9	2.0	16.6	2.2	17.3	3.0	17.3	3.1	24.47**	0.05	15.9	0.1	16.6	0.1	17.2	0.2	17.3	0.1	d = c > b > a
10–12 yrs, N	552		383		376		422												
Age, yrs	11.0	0.8	11.0	0.8	11.0	0.9	10.9	0.9	1.19										
BMI, kg/m^2	17.4	2.3	17.6	2.9	18.5	3.2	18.9	3.4	26.69**	0.05	17.4	0.1	17.5	0.1	18.5	0.1	18.9	0.1	d = c > b = a
13–15 yrs, N	454		324		277		384												
Age, yrs	13.8	0.8	13.8	0.7	14.0	0.8	14.0	0.9	9.12**										
BMI, kg/m^2	19.0	2.6	19.1	2.9	19.9	3.1	20.6	3.5	18.24**	0.04	19.0	0.1	19.2	0.2	19.9	0.2	20.5	0.1	d = c > b = a
Girls																			
7–9 yrs, N	409		259		219		416												
Age, yrs	8.3	0.8	8.2	0.7	8.4	0.6	8.1	0.8	7.63**										
BMI, kg/m^2	15.7	2.1	16.2	2.3	17.0	2.6	17.4	3.6	31.39**	0.07	15.7	0.1	16.2	0.2	16.9	0.2	17.5	0.1	d = c > b = a
10–12 yrs, N	505		377		336		390												
Age, yrs	11.0	0.8	11.0	0.8	11.0	0.8	10.9	0.9	2.07										
BMI, kg/m^2	17.2	2.6	17.7	2.9	18.2	3.3	18.7	3.7	21.61**	0.04	17.2	0.1	17.7	0.2	18.2	0.2	18.8	0.2	d > b = a, c > a
13–15 yrs, N	412		311		288		297												
Age, yrs	13.7	0.7	13.7	0.7	13.9	0.9	13.9	0.9	4.70*										
BMI, kg/m^2	19.7	2.9	19.1	2.8	20.1	3.3	20.3	3.3	6.85**	0.02	19.7	0.2	19.2	0.2	20.0	0.2	20.2	0.2	d = c > b

*$p < 0.01$, **$p < 0.001$
† post-hoc comparisons $p \leq 0.05$
M – means; SD – standard deviations; SE – standard errors

3.3 Estimated changes by decade

Estimated differences in age-adjusted BMIs between adjacent surveys are variable and suggest that secular changes over the three decades are not linear (Table 2). Estimated gains in the BMI over the interval of 30 years are reasonably similar among the three age groups of boys, 1.38 to 1.58 kg/m^2, but decline systematically from 7–9 to 10–12 to 13–15 years among girls, 1.82, 1.59 and 0.32 kg/m^2, respectively. Estimated changes in the BMI between adjacent surveys, in contrast, vary considerably. The major portion of secular gain in the BMI of boys 7–9 years occurs between 1986 and 1996 and 1996 and 2006, while the major portion of the gain among boys 10–12 and 13–15 years occurs between 1996 and 2006 and between 2006 and 2016. Among girls 7–9 and 10–12 years, in contrast, estimated secular gains between adjacent surveys are rather evenly distributed across the three decades, but among girls 13–15 years, the BMI declines between 1986 and 1996, increases markedly between 1996 and 2006 and shows a small gain between 2006 and 2016.

3.4 Prevalence of thinness, OWT, OB

The prevalence of thinness, OWT and OB across surveys is summarized in Table 3. Severe and moderate thinness are low in prevalence over time in boys. Mild thinness is relatively high among boys 7–9 years in 1986 (15.6%), but is lower in subsequent surveys (4% to 9%) and similar to that among boys 10–12 and 13–15 years (6% to 10%). In contrast, OWT increases in prevalence across surveys in the three age groups of boys and is especially higher in 2006 and 2016 compared to 1986 and 1996. Although quite low in 1986, the prevalence of OB systematically increases across surveys in boys 7–9 and 10–12 years; OB is uncommon among boys 13–15 years in 1986 and 1996, and increases slightly in 2006 and 2016.

Among girls, the prevalence of severe and moderate thinness is also relatively low, with no clear trend across surveys. Mild thinness changes negligibly between 1986 and 1996 in each age group, and declines in 2006 and 2016. OWT increases across surveys among girls 7–9 and 10–12 years, while among girls 13–15 years, OWT is lowest in 1996 and ranges from 10% and 14% in the other surveys. The prevalence of OB among girls in the three age groups is low in 1986 and 1996 (< 2%). Among girls 7–9 years, OB increases to 5.9% in 2006 and 11.5% in 2016, which contrasts the smaller increments among girls 10–12 and 13–15 years. The prevalence of OB among girls 7–9 years is double that among girls 10–12 years (5.6%) and more than triple that for girls 13–15 years (2.7%).

4 Discussion

BMIs of rural boys and girls 7–15 years in western Poland increased, on average, across four decennial surveys of the same ten communities spanning 1986 and 2016, but changes between adjacent surveys were variable (Table 2). Relative to 2010 reference data for Poland (Kułaga et al. 2011), median BMIs of rural boys in 2016 approximated the medians at 7 and 8 years, and were above the medians 9–15 years. Median BMIs of girls in 2016 tended to be above the reference medians at most ages. Median BMIs of the rural boys and girls 10–15 years in 2006 and 2016 overlapped those for a combined sample of urban and rural boys and girls in the Greater Poland province surveyed in 2009–2010 (Kaczmarek et al. 2011).

Estimated secular changes in the BMI for the total samples of rural boys and girls 7–15 years between 1986 and 2016 were 0.50 and 0.45 kg/m^2 per decade, respectively. In studies spanning variable time intervals, corresponding estimates for Cracow youth 7–18 years varied among intervals considered, 0.57 kg/m^2 per decade between 1971 and 1983, 0.14 kg/m^2 between 1983 and 2000, and 0.49 kg/m^2 between 2000 and 2010 among boys (Kryst et al. 2012), and

Table 2. Estimated secular changes in the BMI (kg/m^2, means and standard errors based on MANCOVA with age and age^2 as covariates) between 1986 and 2016 (30 years) and between adjacent decennial surveys in boys and girls by age groups.

Age groups (years)		Estimated secular changes in the BMI (kg/m^2)							
		30 years		Adjacent surveys (per decade)					
		1986–2016		1986–1996		1996–2006		2006–2016	
		M	SE	M	SE	M	SE	M	SE
7–9	Boys	1.38	0.18*	0.72	0.19*	0.60	0.23	0.05	0.21
	Girls	1.82	0.19*	0.56	0.22	0.67	0.25	0.59	0.23
10–12	Boys	1.58	0.19*	0.18	0.20	0.99	0.21*	0.41	0.21
	Girls	1.59	0.21*	0.49	0.21	0.53	0.23	0.58	0.23
13–15	Boys	1.44	0.21*	0.21	0.22	0.64	0.25	0.59	0.24
	Girls	0.52	0.23*	–0.55	0.23	0.84	0.25*	0.22	0.25

* $p < 0.05$; M – means; SE – standard errors

Table 3. Prevalence (%) of severe, moderate and mild thinness, overweight and obesity by three-year age groups of rural boys and girls in each decennial survey spanning 1986 and 2016.

Age (years)	Boys						Girls					
	N	Thinness			Owt	Ob	N	Thinness			Owt	Ob
		Sev	Mod	Mild				Sev	Mod	Mild		
7–9 yrs												
1986	441	0.7%	1.8%	15.6%	6.8%	1.4%	409	2.4%	3.4%	13.4%	6.8%	1.0%
1996	272	0	1.1	5.1	7.7	4.0	259	0.8	2.3	11.2	10.8	1.9
2006	218	0.5	0	4.1	16.1	8.7	219	0	0.9	7.3	15.1	5.9
2016	383	0.3	1.6	8.9	16.4	9.4	416	1.7	3.1	9.1	20.7	11.5
10–12 yrs												
1986	522	0.6%	0.6%	8.6%	9.4%	0.8%	505	0.6%	4.2%	13.9%	8.1%	1.0%
1996	383	0	1.6	9.1	8.9	3.1	377	0.3	1.6	13.3	12.7	1.9
2006	376	0	0.5	8.0	18.4	4.5	336	0	1.8	12.2	17.0	4.2
2016	422	0.7	0.9	5.7	20.9	6.4	390	0.5	2.0	9.5	17.9	5.6
13–15 yrs												
1986	454	0.2%	0.4%	9.0%	7.7%	1.3%	412	1.0%	1.2%	10.0%	10.2%	1.2%
1996	324	0	1.2	9.6	12.7	0.6	311	1.3	1.3	14.8	7.1	1.0
2006	277	0.4	0.7	7.6	14.4	2.9	288	0.3	2.1	8.3	14.2	1.4
2016	384	0.5	1.0	6.0	20.6	3.9	297	0	1.7	7.7	13.1	2.7

Sev – severe; Mod – moderate; mild – thinness; Owt – overweight; Ob – obesity; % – prevalence

0.65 kg/m^2 per decade between 1971 and 1983, –0.12 kg/m^2 between 1983 and 2000, and 0.41 kg/m^2 between 2000 and 2010 among girls (Woronkowicz et al. 2012).

In contrast, estimated mean rates of change in the BMI per decade between adjacent decennial surveys (kg/m^2) varied with CA group and between boys and girls (Table 2). For example, BMIs of rural girls 13–15 years declined between 1986 and 1996, –0.55 kg/m^2, while those of rural boys 10–12 and 13–15 years were relatively low, 0.18 and 0.21 kg/m^2, respectively (Table 2). Although not an equivalent interval, BMIs of Cracow girls declined slightly, while those of boys increased only slightly between 1983 and 2000 (see above).

Secular changes in the BMI were reflected in estimates of weight status (Table 3). The prevalence of OWT and OB increased across surveys, and was especially higher in 2006 and 2016 compared to 1986 and 1996. The prevalence of mild thinness, in contrast, declined in 2006 and 2016 compared to 1986 and 1996.

Current focus, however, is more often upon OWT and OB than on thinness (Ng et al. 2014; Garrido-Miguel et al. 2019). In the total samples of rural Poznań youth 7–15 years, the prevalence of OWT changed negligibly in boys and girls between 1986 (8%) and 1996 (10%), but increased in 2006 (~16%) and in 2016 (~18%). The estimated prevalence of OWT among the rural boys (19%) and girls (18%) 7–15 years in the 2016 survey was somewhat higher than age-standardized estimates for Polish boys (15%) and girls (12%) < 20 years in 2013 (Ng et al. 2014). The prevalence of OB in the 2016 survey of rural youth was ~7% in both sexes and identical to that for the age-standardized sample < 20 years in 2013 (Ng et al. 2014).

4.1 Weight status among Polish children and adolescents

Results of the present study of rural boys and girls in four surveys spanning 1986 and 2016 are plotted related to comparative data from surveys in Poland in Fig. 2. The comparative data included national surveys in select large cities, small towns and select villages in the same district as the towns in 1966, 1978, 1988 and 2012; the last survey, however, did not measure the anticipated target population (Gomuła et al. 2015). Other comparative data included surveys of school youth in Cracow in 1971, 1983 and 2000 (Chrzanowska et al. 2007), in the Podlaskie province northeast of Warsaw in 1986 and 2006 (Saczuk & Wasiluk 2014), and in the Podkarpackie province east of Cracow in 1998 and 2008 (Mazur et al. 2014). Like the present study, the latter two surveys were conducted in the same schools, except for the 2006 survey in Podlaskie which added several schools. Recent national surveys in 2001 (Małecka-Tendera et al. 2005) and 2010 (Kulaga et al. 2011) were also included in the comparative data. Surveys in Podlaskie used the same age groups as the present study. Others reported estimates for single year age groups; estimated prevalence for the combined CA groups used in the present study was calculated

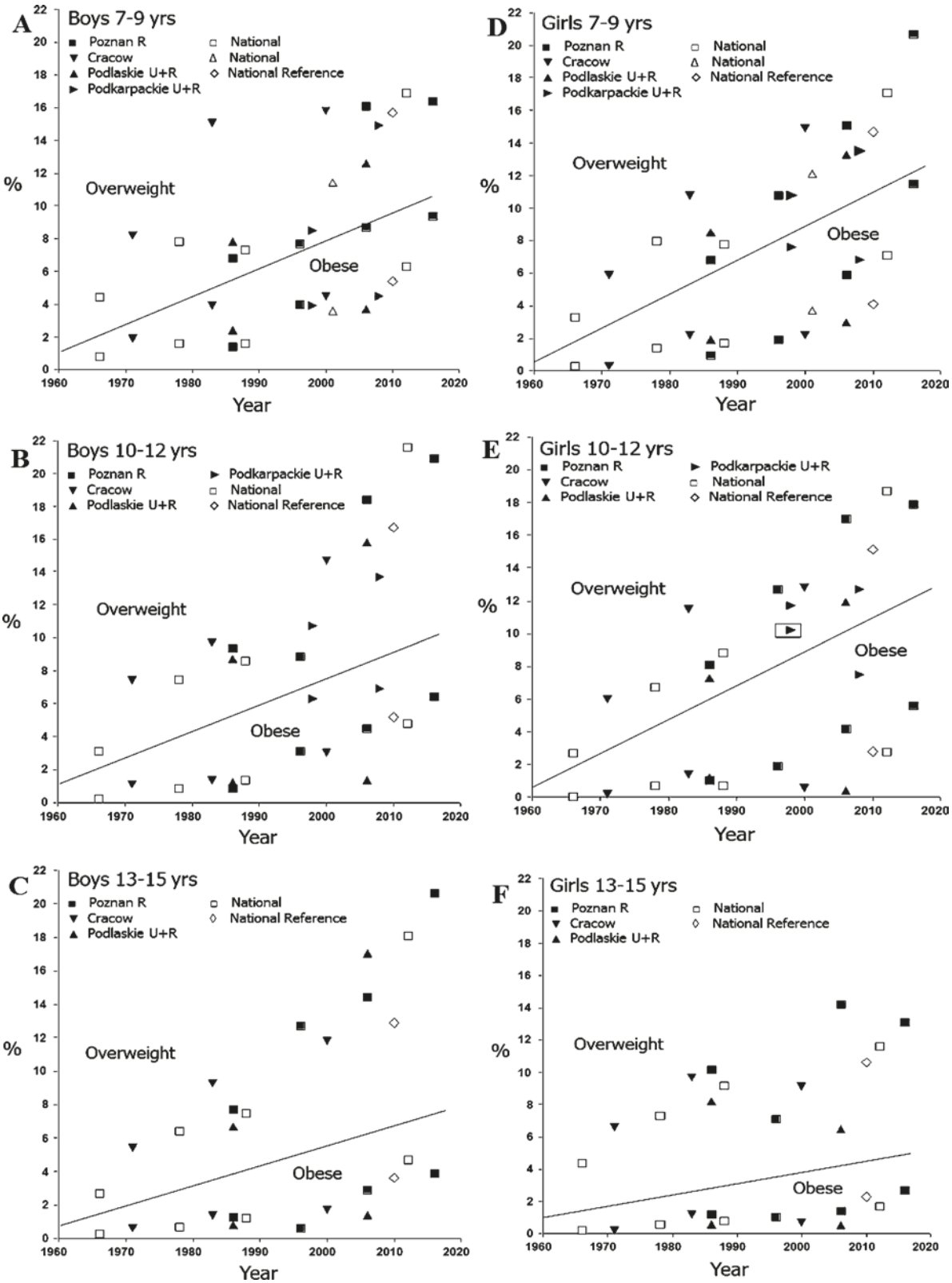

Fig. 2. Prevalence of overweight and obesity in the four surveys of rural boys and girls, and in surveys of Polish boys and girls by age group: 7–9 years (**A** – boys, **D** – girls), 10–12 years (**B** – boys, **E** – girls) and 13–15 years (**C** – boys, **F** – girls). Comparative data are from national surveys in 1966, 1978, 1988 and 2012 (Gomuła et al. 2015); surveys in the city of Cracow in 1971, 1983 and 2000 (Chrzanowska et al. 2007), the Podlaskie province in 1986 and 2006 (Saczuk & Wasiluk 2014), and the Podkarpackie province in1998 and 2008 (Mazur et al. 2014); and national surveys in 2001 (Małecka-Tendera et al. 2005) and 2010 (Kułaga et al. 2011).

from sample sizes and frequencies or percentages of OWT and OB in single year CA groups in each study.

Overall, trends in OWT and OB among the rural boys and girls between 1986 and 2016 were consistent with and overlapped trends in Poland over the past two generations. Among boys 10–12 years (Fig. 2B) and 13–15 years (Fig. 2C), the prevalence of OWT across surveys increased in a linear manner over time. The trend was similar among boys 7–9 years (Fig. 2A), except for a high prevalence of OWT in the 1983 survey of Cracow boys.

Obesity increased, in general, in the 1990s among boys 7–9 years (Fig. 2A) and 10–12 years (Fig. 2B). Prevalence was highest among rural Poznań boys 7–9 years in 2006 and 2016 (just under 10%), and among Poznań and Podkarpackie boys 10–12 years (about 6%). The prevalence of OB among boys 13–15 years (Fig. 2C) was low (≤ 2%) from the 1960s to 2000, and increased slightly to 2016 (about 4%).

Overweight also increased linearly over time among girls 7–9 (Fig. 2D) and 10–12 years (Fig. 2E). The trend for girls 13–15 years (Fig. 2F) was more variable since the 1990s, but OWT among rural Poznań girls in 2006 and 2016 tended to be among the highest.

Among girls 7–9 (Fig. 2D) and 10–12 (Fig. 2E) years, OB was relatively low in prevalence through the 1990s, but generally higher more recently. Poznań girls 7–9 years in 2016 had the highest prevalence of OB (~12%), while Podkarpackie girls 10–12 years had the highest prevalence of OB in 1998 (~10%, indicated by an asterisk in the figure) and 2008 (~7%). Among girls 13–15 years (Fig. 2F), OB was quite low between 1966 and 2012 (≤ 2%), and approached 3% among rural Poznań girls in 2016.

The prevalence of severe and moderate thinness was relatively low over time in both boys and girls with no clear trend across surveys. However, mild thinness approached 15% s among boys 7–9 years in 1986, but declined in subsequent surveys of boys 7–9 years (4% to 9%) and was similar to that among boys 10–12 and 13–15 years (6% to 10%). Among girls, mild thinness changed negligibly between 1986 and 1996 in each age group, and declined in 2006 and 2016.

Secular data for thinness are limited. Estimated prevalence of severe, moderate and mild thinness among rural boys and girls 13–15 years in the 2016 survey (Table 3) was similar to that for a sample of urban and rural boys and girls 13–18 years from the Greater Poland province in 2009–2010 (Durda 2011). Mild thinness was relatively more common in 1986 and declined slightly in 2006 among youth 10–12 and 13–15 years (Table 3). In contrast, mild thinness was rather high among rural Poznań children 7–9 years in 1986 (boys 15.6%, girls 13.4%), but declined in 2016 (boys 4.1%, girls 7.3%). Estimates for mild thinness among children 7–9 years in the Podlaskie province (Saczuk & Wasiluk 2014) were lower in 1986 (boys 7.3%, girls 11.5%) and changed negligibly in 2006 (boys 8.9%, girls 12.8%).

4.2 Secular change in weight status and transformations in Poland

Major political, economic and social changes characterized the state of affairs in Poland during the interval spanning the four decennial surveys. Nevertheless, living conditions, nutritional status and health care during the transitions were apparently sufficient to support secular increases in the heights and weights (Bartkowiak et al. 2021a) and BMIs of the rural boys and girls 7–15 years between 1986 and 2016 (Tables 2 and 3).

Conditions in Poland at the time of the respective surveys merit consideration. Poland had a centrally controlled economy which was faltering at the time of the major strikes by workers in the early 1980s. Martial law was imposed from 1981 through 1983. The economy floundered given the need to repay foreign debt and eventually collapsed resulting in a deficit of goods for the internal market, decline in real income by one-half and major inflation. The government collapsed during the 1980s and democratic elections were held late in 1991.

Of relevance, the samples of boys and girls the 1986 and 1996 surveys were born in the 1970s and 1980s, respectively, while the 1996 sample grew-up in a democratic country with a struggling free market economy. The sample of the 2006 survey was born during this interval of economic uncertainty. Subsequent reforms and associated economic development resulted in European Union membership for Poland in 2004, which was followed by an influx of funds, part of which was allocated for the modernization of farms. By inference, living conditions for children in the 2006 and 2016 surveys were improved relative to those for children in the earlier surveys (Gomuła et al. 2015; Saczuk 2018).

Although community specific data are not available, it is reasonable to assume that conditions in each community across surveys interacted with the major transitions occurring in Poland. Changes in the agricultural sector were especially relevant given that the communities studied were dependent upon agriculture. Many people from rural areas worked in state-owned farms, which became unprofitable as a result of economic changes in the country (Urbanowska-Sojkin & Banaszyk 2009). The per unit price of products produced by farmers in 1990 to 1991 also declined by 63%, while real farm income declined > 40% and wages of employees declined by about 37% (Kowalik 2009). With the shift to a market economy in 1991, state farms were liquidated, unemployment and alcoholism increased drastically and the standard of living decreased.

Dietary and physical activity are two factors often indicated as central to secular changes in weight status, specifically OWT and OB (Lobstein et al. 2004; Hu 2011). As inflation increased during the 1970s, access to food products was limited and food rationing was instituted in the mid-1970s, first for sugar, then for meat and meat products, and eventually for butter, flour cereal and rice. Families were allocated vouchers or ration cards (Zawitowski 2017). In

rural areas, rationed foods were often supplemented with foods produced for personal consumption (milk, butter, eggs, chicken, duck, pork) and by barter (meat for butter, eggs for milk, etc.). After the political changes of the 1980s and gradual opening of the market, processed foods regularly entered Poland.

Of potential relevance to secular changes in weight status, daily food rations of school youth in the city of Poznań showed minor differences between 1980 and 1990. The estimated average daily consumption of calories and specific nutrients among girls 13–15 years was 2278 ± 628 kcal (61 g protein, 102 g fat, 280 g carbohydrates) in 1980 and 2144 ± 728 kcal (59 g protein, 87 g fat, 282 g carbohydrates) in 1990. Daily estimates for boys 13–15 years were 2597 ± 879 kcal (74 g protein, 121 g fat, 303 g carbohydrates) in 1980 and 2538 ± 848 kcal (68 g protein, 105 g fat, 331 g carbohydrates in 1990 (Przyslawski et al. 1998).

Surveys of eating habits and food consumption among adolescents suggested an increase of processed and "fast foods" between 1990 and 2000 (Augustyniak & Brzozowska 2002). Although rural adolescents consumed fewer calories than urban peers, both groups showed an increase in energy from fat and a decrease in energy from carbohydrates and proteins, while daily intakes were deficient in minerals – calcium, magnesium, copper and especially iron among girls.

More recently, the percentage of Polish youth 13–15 years consuming vegetables daily changed negligibly between 2002 and 2018, 36.6% to 34.2%, while percentages consuming fruits daily increased, 23.1% to 38.2%; on the other hand, percentages consuming sweets and sweet drinks increased more than threefold between 2002 and 2018, 18.1% to 69.9% and 12.7% to 44.9%, respectively (Augustyniak & Brzozowska 2002; Woynarowska & Mazur 2012; Mazur 2015; Mazur & Małkowska-Szkutnik 2018).

Data addressing levels of physical activity among Polish children and youth are apparently not available prior to 1990, while recent data are largely limited to adolescents. Estimated percentages of 11, 13 and 15 year old boys reporting vigorous physical activity (VPA) 4–7 days per week between 1990 and 1998 were 54%, 51% and 42%, respectively, but declined in 2018 to 43%, 37% and 35%, respectively. By inference, percentages of boys not reporting VPA 4–7 days per week increased over time. Percentages of girls reporting VPA were lower and declined negligibly between the 1990s and 2018, 38% to 36% at 11 years and 31%, to 27% at 13 years Among girls 15 years, percentages reporting VPA 4–7 days per week were lower and stable over time, 20% in the 1990s and 22% in 2018 (Woynarowska & Mazur 2012; Mazur 2015; Mazur & Małkowska-Szkutnik 2018).

With a modified indicator moderate-to-vigorous physical activity (MVPA), which included mandatory school physical education (4 hours/week since 2003), percentages of Polish boys reporting MVPA seven days per week in five surveys spanning 2002 to 2018 were rather low, 24% to 34% at 11 years, 16% to 29% at 13 years and 16% to 25% at 15 years. Percentages of girls reporting MVPA seven days per week across the same interval were lower, 18% to 27% at 11 years, 12% to 18% at 13 years, and 8% to 11% at 15 years (Woynarowska & Mazur 2012; Mazur 2015; Mazur & Małkowska-Szkutnik 2018). By inference, the overwhelming majority of Polish youth 11–15 years did not report MVPA on a daily basis between 2002 and 2018. Of note, high levels of VPA and MVPA are associated with a lower risk of obesity independent of sedentary behavior (Katzmarzyk et al. 2015).

The physical fitness of the rural boys and girls in the present study was also assessed in each of the four decennial surveys (Bartkowiak et al. 2021b). Speed (sprint) and flexibility (stand and reach) declined over this interval, while power (vertical jump) and cardiovascular fitness (step test index) changed variably across surveys. Agility (figure-of-8 run) improved between 1986 and 1996, but changed negligibly in subsequent surveys. The results for the rural youth were generally consistent with other studies of the fitness of Polish school youth that spanned a similar interval (Bartkowiak et al. 2021b). Given the variable trends in fitness tests between 1986 and 2016, it is difficult to make inferences about changes in the physical activity of the rural boys and girls. Nevertheless, the overall lack of improvement in physical fitness, especially cardiovascular fitness, across the four surveys suggests inadequate levels of habitual physical activity. It must be noted, however, that although physical activity and physical fitness are significantly related, most of the variance in fitness is not accounted for by physical activity (Malina 1995; Malina 2001; Malina et al. 2016).

On a more general level, the 2018 Physical Activity Fact Sheet for Poland (World Health Organization 2018) noted that only 19% of girls and 30% of boys 11–15 years were classified as having a sufficient level of physical activity for health and fitness, while the 2018 Physical Activity Report Card for Poland concluded that "…the proportion of children and youth who meet the recommended levels of PA … remains low" (Zembura et al. 2018: 396). The latter was based on several indicators of activity and inactivity,

The preceding discussion was largely focused on indicators of diet and physical activity for Polish youth 11+ years of age. Corresponding estimates for younger children are limited. A recent survey in northwestern Poland (Szczecin) between 2016 and 2018 utilized parental report to estimate diet and activity behaviors of children 8–10 years (Ratajczak & Petriczko 2020). Approximately 46% of the children consumed sweets several times per week while 28% consumed sweets daily, and 43% consumed fast foods 3–5 times per week. Percentages of children participating in physical activity for 5 or more hours per week were 45% for boys and 40% for girls, and for 3–5 hours per week were 33% in each sex. The intensity of activity was not considered. In contrast, daily television viewing (i.e., sedentary behavior) for 1–3 hours and for > 3 hours was reported for, respectively, 54% and 23% of the children; differences between boys and

girls were negligible. Although based on parental report, increased consumption of sweets and time spent viewing television, and less time in physical activity were also associated with an elevated BMI (Ratajczak & Petriczko 2020).

Changes in lifestyle associated with diet, reduced physical activity and increased sedentary behaviors (physical inactivity) are generally accepted as major factors associated with the increased prevalence of OWT and OB among children and adolescents. Other factors must also be considered, e.g., interactions with environmental factors (Bray & Champagne 2005; Keith et al. 2006). It is possible, for example, that stresses associated with the political unrest and economic and social insecurities in Poland during the interval spanning the surveys may have influenced living conditions in the communities and may have contributed, in part, to the increased prevalence of OWT and OB. With the liquidation of state farms in the 1990s, for example, services for rural communities were affected. Perhaps most relevant, among other changes, was the reduction in bus connections and railway lines, which likely influenced job opportunities. Unemployment claims indicating state-owned farms as the last place of employment was 100,000 in 1991 and declined by about one-half in 2004 as approximately 48,000 of unemployed individuals received a job or a job offer (Zgliński 2003). With the deterioration of agricultural conditions, alcoholism, passivity and perceptions of helplessness increased in many rural communities of Poland (Halamska 2011; Górecki 2015). As a result, home conditions of some children and youth may have been significantly altered during the political and economic upheaval in Poland in association with job insecurity and perhaps alcoholism among a parent or both. Such home conditions may have contributed to adverse childhood experiences for some children, for example, neglect, abuse, parental conflict, among others (Fahrenkamp 2018). In addition to potential effects on growth status (Oh et al. 2018), adverse childhood experiences have been related to overweight and obesity during adolescence (Gardner et al. 2019) and in adulthood (Fahrenkamp 2018).

4.3 Overview

Secular changes in the BMIs of rural boys and girls between 1986 and 2016 were significant, and suggested a gradient in age-adjusted means: 2016 > 2006 > 1996 > 1986, except among girls 13–15 years. Estimated changes between adjacent decennial surveys, however, were variable. Changes in OWT and OB between 1986 and 2016 were consistent with other studies in Poland over the past two generations The trends spanning the 1996, 2006 and 2016 surveys were consistent with recent dietary changes, i.e., increased consumption of processed and "fast foods" and of sweets and sweet drinks, and with reduced levels of regular physical activity, specifically VPA and MVPA, among Polish youth since the 1990s. Other factors that may impact the weight status of youth merit more detailed attention.

The study is not without limitations. First, an indicator of biological maturity status was not included in the early surveys. Status quo menarcheal information was included in the 2016 survey; estimated mean age at menarche in 2016 was 13.3 years, which was similar to corresponding data for rural girls in Poland (Barkowiak et al. 2021c). Second, information on changes in dietary habits and overall lifestyle in the respective communities and changes in physical activity habits of children and adolescents over time was lacking. Nevertheless, the study is unique in that school children and adolescents in the same ten communities were surveyed on four occasions spanning 30 years.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Supplementary Table 1. Sample size, age and the BMI by single year chronological age groups in the four decennial surveys of boys (M, mean; SD, standard deviation; MD, median).

Age group	n	Age (yrs)		BMI (kg/m^2)			n	Age (yrs)		BMI (kg/m^2)		
		M	SD	M	SD	MD		M	SD	M	SD	MD
	1986						1996					
7	75	7.2	0.2	15.3	1.7	15.2	64	7.2	0.2	16.2	1.8	15.9
8	189	8.0	0.3	15.9	2.2	15.5	115	8.0	0.3	16.3	1.8	16.0
9	177	9.0	0.3	16.3	2.0	15.9	93	9.0	0.3	17.4	2.6	16.8
10	175	10.0	0.3	16.8	2.2	16.3	114	10.0	0.3	17.1	2.7	16.5
11	186	11.0	0.3	17.3	2.3	16.8	137	11.0	0.3	17.4	2.6	16.8
12	161	12.0	0.3	18.0	2.4	17.5	132	11.9	0.3	18.1	3.4	17.2
13	171	13.0	0.3	18.4	2.6	17.8	128	13.0	0.3	19.0	2.9	18.3
14	171	13.9	0.3	19.0	2.7	18.6	130	14.0	0.3	18.9	2.7	18.3
15	112	14.8	0.3	19.7	2.3	19.4	66	14.8	0.2	19.8	3.0	19.3
	2006						2016					
7	48	7.2	0.2	16.3	1.7	15.7	100	7.2	0.2	16.7	2.9	15.9
8	79	8.0	0.3	17.4	3.4	16.1	151	8.0	0.3	17.1	3.2	16.0
9	91	9.0	0.3	17.7	3.0	17.0	132	9.0	0.3	18.0	3.1	17.4
10	123	10.0	0.3	17.9	3.1	17.4	145	9.9	0.3	18.2	3.3	17.7
11	128	11.0	0.3	18.6	3.3	18.0	144	10.9	0.3	19.1	3.4	18.4
12	125	12.0	0.3	19.0	3.3	18.2	133	12.0	0.3	19.5	3.5	18.9
13	92	13.0	0.3	19.7	3.7	19.1	128	13.1	0.3	19.9	3.4	19.3
14	103	14.0	0.3	19.6	2.7	19.0	119	13.9	0.3	20.3	3.2	19.9
15	82	15.0	0.3	20.6	2.9	20.3	137	15.0	0.3	21.5	3.8	20.5

Supplementary Table 2. Sample size, age and the BMI by single year chronological age groups in the four decennial surveys of girls (M, mean; SD, standard deviation; MD, median).

Age group	n	Age (yrs)		BMI (kg/m^2)			n	Age (yrs)		BMI (kg/m^2)		
		M	SD	M	SD	MD		M	SD	M	SD	MD
	1986						1996					
7	79	7.2	0.2	15.3	2.4	15.0	49	7.1	0.2	15.5	1.8	15.2
8	160	8.0	0.3	15.5	1.8	15.4	109	8.0	0.3	16.2	2.2	15.7
9	170	9.1	0.3	16.0	2.2	15.7	101	8.9	0.3	16.6	2.6	16.1
10	149	10.0	0.3	16.5	2.2	16.3	120	10.0	0.3	17.6	3.0	16.9
11	186	11.0	0.3	17.1	2.7	16.5	133	11.0	0.3	17.5	2.6	16.8
12	170	12.0	0.3	17.9	2.5	17.5	124	12.0	0.3	18.0	2.9	17.3
13	179	13.0	0.3	19.1	2.8	18.6	129	13.0	0.3	18.7	2.8	18.3
14	155	14.0	0.3	20.0	2.9	19.6	118	14.0	0.3	19.3	2.9	18.9
15	78	14.8	0.2	20.5	2.8	19.7	64	14.7	0.1	19.7	2.5	19.4
	2006						2016					
7	20	7.4	0.1	18.0	3.3	17.1	123	7.1	0.3	16.6	3.0	15.8
8	97	8.0	0.3	16.7	2.3	16.4	146	8.0	0.3	17.4	3.5	16.8
9	102	9.0	0.3	17.0	2.8	16.4	147	9.0	0.3	18.1	4.1	17.0
10	113	10.0	0.3	17.3	2.8	16.6	140	10.0	0.3	17.8	3.4	17.0
11	126	11.0	0.3	18.7	3.4	18.1	137	11.0	0.3	18.8	3.4	18.3
12	97	12.0	0.3	18.6	3.5	17.8	113	12.0	0.3	19.7	4.2	19.0
13	106	13.0	0.3	19.4	3.7	18.7	111	13.0	0.3	19.7	3.7	19.0
14	104	14.0	0.3	20.3	3.1	19.9	96	13.9	0.3	20.4	3.3	19.5
15	78	15.0	0.3	20.7	3.0	19.8	90	15.0	0.3	21.0	2.7	20.5

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Age at menarche among rural school youth in west-central Poland: variation with weight status and population growth

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ABSTRACT: Studies of age at menarche in Poland have a long history and consistently show an urban-rural gradient. The objectives of the study were to to estimate the age at menarche among school girls resident in ten rural communities of the Greater Poland province in 2016 and to compare ages at menarche by weight status and by population growth. The sample included 1146 girls, 7–16 years of age, resident in ten rural communities. Menarcheal status was obtained via interview. Heights and weights were measured; the BMI was calculated. Based on the latter, the girls were classified as thin, normal weight and overweight (including the obese) relative to IOTF criteria. Population growth between 1986 and 2016 in each community was estimated from local records. Ages at menarche were estimated with the probit regression protocol (SPSS) using the logistic model with log 10 transformation for the total sample and for the subsamples by weight status and population growth. The median age at menarche for the total sample of rural girls was 13.25±0.20 years. Menarche was earlier among Overweight (13.06±0.32 years) compared to Normal Weight (13.25±0.37 years) and Thin (13.81±0.41 years), and among girls resident in communities with Major population growth (12.58±0.44 years) compared to Little/No growth (13.65±0.14 years). Results of the present survey were generally consistent with recent surveys of age at menarche among rural girls in Poland and among girls classified by weight status. Corresponding comparative data relating menarche to population growth are lacking.

KEY WORDS: puberty, thinness, overweight, BMI, population growth

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Introduction

Age at menarche is a commonly used indicator of maturity among adolescent girls and women. It is a relatively late indicator in the sequence of pubertal events and occurs, on average, after peak height (Malina et al. 2004). There is also a relatively long tradition of reporting ages at menarche in Europe and North America. In Europe, for example, mean ages at menarche in the late 19th century were about of 16–17 years, and evidence from several European countries suggests a decline in age at menarche by about 3.6 months per decade (Ong et al. 2006). The secular decline was generally related to improvements in health and nutritional conditions over time associated with conditions of living and improvements in socioeconomic conditions (Nieczuja-Dwojacka et al. 2018). In the context of the recent leveling of secular changes in age at menarche in many populations, it has been suggested that mean age at menarche in some populations may be approaching a "genetic limit" given reduced associations with socioeconomic and environmental factors (Golding et al. 2001).

Corresponding data from the end of the 19th century for the Polish population indicate a median age at menarche of 15.2 years (Kowalska 1966). Consistent with data for Europe, age at menarche in Polish girls has also declined over time, allowing for variation associated with the two world wars and major political transformation in the 1980s. Although based on retrospective data, mean age at menarche among college women born before WWII, 14.2±1.2 years, was slightly earlier than among women born during the war, 14.4±1.3 years, and both were later than that of women born after the war, 13.9±1.3 years (Liczbińska et al. 2018). A review of three large scale surveys in different regions of Poland spanning 1967 through 2007 noted secular declines and persistence of the urban-rural contrast in ages at menarche in national and regional samples, and also noted corresponding contrasts between rural girls who were from farming and non-farming families (Łaska-Mierzejewska et al. 2016). More recently, a summary of national surveys in Poland noted secular declines and persistence of urban-rural contrasts in means ages at menarche between 1966 and 2012 (Gomula and Kozieł 2018). Overall, several studies noted that ages at menarche of girls resident in rural areas were consistently later, on average, than in urban girls, while daughters of rural non-farming families attained menarche earlier than girls from farming families.

Studies in Poland and other countries have noted a variety of factors associated with or that are correlates of age at menarche including, for example, nutritional status, socioeconomic status, family size, parental education, ethnicity, area of residence, psychological and emotional factors, and others (Łaska-Mierzejewska et al. 2016; Malina et al. 2004). In addition, weight status defined by weight *per se* and weight-for-height indices such as the ponderal index and the BMI, is also related to age at menarche (Hillman et al. 1970; Himes et al. 2009; MacMahon 1973; Merzenich et al. 1993).

Current studies on the age at menarche of girls resident in the Greater Poland voivodship are largely limited to urban samples (Durda 2011; Durda-Masny et al. 2019; Kaczmarek 2001, 2002). The purpose of the present study is to estimate the age at menarche among girls 7–16-years of age resident in ten rural communities of the Greater Poland province in 2016. Age at menarche is ad-

dressed from three perspectives: in the total sample, among girls classified by weight status as thin, normal weight or overweight, and among girls resident in communities which have experienced major population growth compared to those in communities with little or no population growth over 30 years (1986–2016).

Material and Methods

Background

The growth status of rural school children and adolescents in 10 rural communities in the Greater Poland province (Wielkopolskie) in west central Poland was surveyed in four decennial surveys spanning 1986 and 2016 (Bartkowiak et al. 2020). The communities were located between 19 and 75 kilometers of the city of Poznań, the capital of the voivodeship. The communities were initially selected in 1986 in cooperation with the provincial Board of Education and Development in Poznań and with the approval of the respective community authorities to represent different regions of the province. Subsequent surveys in 1996, 2006 and 2016 were also conducted with the approval of provincial and respective community authorities. The present study is limited to the 2016 survey during which information on the menarcheal status of girls was surveyed. Earlier surveys did not include menarcheal information.

Ethics

The 2016 survey was approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (No. 907/16) and educational authorities of each community. Parents or legal guardians provided written informed consent for their child or children to participate, while the latter provided assent for their participation. The surveys were conducted by faculty and staff of the University of Physical Education in Poznań in cooperation with teachers at each school.

Sample

The study included 1146 girls 7–16 years of age from the ten communities. Chronological age (CA) groups spanned one year with the whole year as the midpoint of the interval (7 years = 6.50 to 7.49, etc.).

Age at menarche

Menarcheal status was obtained via interview. Each girl was individually interviewed by a female member of the research staff as to whether menarche had occurred (yes) or had not yet occurred (no).

Anthropometry

Height (0.1 cm) and weight (0.1 kg) were measured during the school day in the gymnasium of each community. Experienced staff of the Department of Anthropology and Biometry of the Poznań University of Physical Education made all measurements using established procedures (Bartkowiak et al. 2020).

Weight status

The BMI (kg/m^2) was calculated and used to classify the girls by weight status using age- and sex-specific IOTF criteria (Cole et al. 2000, 2007). Given limited numbers of girls classified as severely (n=9) and moderately (n=26) thin, they

were combined with girls classified as mildly thin (n=100) into a single group labeled as Thin (n=135, 11.8%). Similarly, relatively few girls were classified as obese (n=79), and they were combined with those classified as overweight (n=201) into a single group labeled as Overweight (n=280, 24.4%).

Population growth

After the fourth survey was completed, the population records of the 10 communities were extracted from locally available archives (Supplementary Table 1). Between 1986 and 2016, five communities increased in population size, +1236 to +7436 individuals compared to the other five communities which increased to a lesser extent or decreased in population, +546 to -1920 individuals (Statistical yearbook of the Poznań voivodeship 1987; Wielkopolskie Voivodship. Subregions – Powiats – Gminas 2017). The two groups were labeled, respectively, as having experienced Major or Little/No population growth across the interval of the four surveys. The distributions of girls by weight status in communities with major growth (Thin = 12.3%, Normal = 65.4%, Overweight = 22.3%) versus little/no growth (Thin = 11.4%, Normal = 62.6%, Overweight = 26.0%) did not differ (Kappa = 0.03, Chi square = 2.08).

Analysis

Ages at menarche were estimated with the probit regression protocol of IBM SPSS Statistics 19. The logit model with log 10 transformation was used. Four separate analyses were calculated, first for the total sample; for the subsamples of girls classified as Thin, Normal Weight, and Overweight; for samples of girls from the communities which experienced Major and Little/No growth; and for samples of Thin and Overweight girls from communities with Major and Little/No growth; numbers of Thin girls by age groups were too small for analysis. Median ages, 95% confidence intervals, standard errors and standard deviations are reported. The significance of differences between pairs of ages at menarche was estimated with standard errors calculated from the median and 95% confidence intervals.

Results

The median age at menarche for the total sample of rural girls in 2016 was 13.25±0.20 years with 95% confidence intervals of 12.91 to 13.64 years. Corresponding estimates for the girls classified by weight status are summarized in Table 1. Menarche occurred earliest, on average, among Overweight girls (13.06±0.32 years), followed by Normal Weight girls (13.25±0.37 years) and Thin girls (13.81±0.41 years). The range of the 95% confidence intervals was smaller among Overweight girls (1.1 years) compared to Normal Weight and Thin girls (1.3 and 1.4 years, respectively). The difference in ages at menarche between Overweight and Thin girls approached significance; other pairwise comparisons were not significant.

Estimated ages at menarche among girls resident in communities which experienced Major and Little/No population growth are summarized in Table 2. Age at menarche among girls in the former communities was, on average, significantly earlier than that among girls resident in communities Little/No population growth, 12.58±0.44 and 13.65±0.14 years, respectively. Corre-

Table 1. Samples sizes and descriptive statistics for chronological age and estimated age at menarche among rural girls classified by weight status

Weight status	Age (yrs)			Age at Menarche (yrs)				
	N	M	SD	Median	95%	CI	SE	SD
Thin	135	10.3	2.4	13.81	13.34	14.73	0.47	1.49
Normal	731	11.2	2.6	13.25	12.65	13.98	0.37	1.17
Overweight	280	10.2	2.4	13.06	12.59	13.68	0.32	1.01

Table 2. Samples sizes and descriptive statistics for chronological age and estimated age at menarche among rural girls from communities experiencing Major and Little/No population growth between 1986 and 2016

Population growth	Age (yrs)			Age at Menarche (yrs)				
	N	M	SD	Median	95%	CI	SE	SD
Major	480	10.6	2.6	12.58	11.93	13.45	0.44	1.40
Little/no	666	11.0	2.6	13.65	13.39	13.93	0.14	0.45

sponding 95% confidence intervals indicated relatively little overlap in the estimated ages at menarche between groups.

Among girls from the communities with Major growth, median ages at menarche were 12.12±0.49 years (95% CI 11.48–13.09 years) in Overweight and 12.54±0.15 years (95% CI 12.25–12.84 years) in Normal Weight girls. Corresponding estimates for the communities with Little/No growth were 13.46±0.40 years (95% CI 12.92–14.25 years) in Overweight and 13.62±0.18 years (95% CI 13.30–13.97 years) in Normal Weight girls. Differences in median ages at menarche in girls from communities which experienced Major or Little/No growth within each weight status group were significant.

Discussion

Age at menarche in the total sample of rural girls 7–16 years in west-central Poland in 2016 was 13.25years (95% CI 12.91–13.64 years), and was similar to ages at menarche in rural girls from families of farmers (13.32±1.98 years), of farm-workers (13.19±1.67 years) and of non-farmers (13.17±1.96 years) resident in four geographic regions of Poland in 2001 (Łaska-Mierzejewska and Olszewska 2007). The age at menarche of the 2016 sample of rural girls in the present study was slightly later than ages at menarche noted among girls 7–18 years resident in small towns 13.11 years (95% CI 12.88–13.35 years, n=664) and in rural villages, 13.11 years (95% CI 12.91–13.32 years, n=802) in a 2012 survey of seven districts in Poland (Gomula and Kozieł 2018).

The prevalence of Thinness among rural girls in the present survey was 11.8%, which was similar to that recently reported for rural girls 7–12 years in southern Poland in 2009–2011, 13.3% (Suder et al. 2020). The prevalence of Overweight (i.e. overweight + obesity) in the present sample, 24.4%, was within the range estimates for recent samples of Polish girls 7–15 years; however, overweight rather than obesity was somewhat more prevalent in younger girls 7–12 years in the present study (Bartkowiak et al., under review).

The earlier estimated age at menarche in the sample of overweight and obese

girls compared to normal weight and thin girls was consistent with observations in Poland. In a longitudinal series of urban girls in Poznań, ages at menarche were 12.33±1.46 years among 38 overweight girls, 12.48±0.92 years among 172 normal weight girls, and 13.90±0.13 years among 33 underweight girls (Durda-Masny et al. 2019). The mean age at menarche for urban underweight girls was similar to that for rural thin girls in the present study (13.81±1.49 years), while those for overweight and normal weight girls were earlier than overweight (13.06±1.01 years) and normal weight (13.25±1.17 years) rural girls in the present survey (Table 1). Nevertheless, results of the studies were also consistent with observations in other countries, specifically earlier ages at menarche among overweight and obese girls (Anderson and Must 2005; Biro et al. 2018; Bratke et al. 2017; Himes et al. 2009; Lazzeri et al. 2018).

The contrast in ages at menarche in the total samples of girls and also in the samples of Overweight and Normal Weight girls resident in the rural communities that experienced Major compared to Little/No population growth between 1986 and 2016 merits attention. The data suggested a difference of about one year in age menarche in the respective total samples and subsamples by weight status. The communities which experienced a major population increase were located relatively close to Poznań, 19 to 37 km, while those which experienced little or no population increase were located a bit further from Poznań, 37 to 75 km. The population increase in the former was perhaps related to in-migration from Poznań as the communities were now suburbs of the major city. Of potential relevance, only one of the five communities which experienced major growth showed an increase in birth rates, while among the remaining nine communities, changes in estimated birth rates were negligible in three and declined in the other six communities.

Conclusions

The median age at menarche in the total sample of rural girls resident in the Greater Poland province in 2016 was 13.25±0.20 years, and was generally consistent with recent surveys of rural Polish girls. Age at menarche was earlier among Overweight (13.06±0.32 years) compared to Normal Weight (13.25±0.37 years) and Thin (13.81±0.41 years), which was generally consistent with ages reported for overweight and underweight urban girls in the city of Poznań. Of interest, girls resident in communities which experienced Major population growth between 1986 and 2016 attained menarche earlier, 12.58±0.44 years, compared to girls resident in communities with Little/No population growth, 13.65±0.14 years. The population increase in the former, which were now suburbs of a major city, was perhaps related to in-migration from Poznań. The distribution of girls by weight status did not differ between communities classified by population growth, but estimated ages at menarche in Overweight and Normal Weight girls in the communities with Major growth were earlier than the corresponding groups of girls in the communities with Little/No population growth.

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Kozieł 2018) were provided by Professor Kozieł. His assistance is acknowledged and greatly appreciated. The 2016 survey was funded by a grant from the Ministry of Science and Higher Education – Development of Young Researchers (Sylwia Bartkowiak).

The Authors' contributions

The study was designed and conceived by SB, JJ, MK, RS. Field work was carried out by SB, JMK, JJ, MK, RS. Analysis and interpretation of the results were conducted by SB, JMK, RMM. The manuscript was written by SB, JMK, RMM

Conflict of interest

The authors declare that there is no conflict of interest.

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Supplementary Table 1. The ten rural communities ranked by population growth between 1986 and 2016[1]

	Distance to Poznań (km)	1986	2016	Population change
Major growth				
Biedrusko	19	9307	16743	+7436
Strykowo	31	12395	14973	+2578
Pamiątkowo	24	27530	29828	+2298
Wojnowice	35	14861	16391	+1530
Nekla	37	6215	7451	+1236
Little/no growth:				
Kłecko	75	7046	7592	+546
Kwilcz	62	6002	6395	+393
Granowo	37	4676	5051	+375
Kołaczkowo	59	6110	6084	−26
Obrzycko	46	6444	4524	−1920

[1]Extracted from Statistical yearbook of the Poznań Voivodeship (1987) and Wielkopolskie Voivodship. Subregions–Powiats–Gminas (2017).

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Human Kinetics
ORIGINAL RESEARCH

Physical Fitness of Rural Polish School Youth: Trends Between 1986 and 2016

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Background: The objective of the study was to evaluate secular changes in the physical fitness of rural school youth, 7–15 years, in west-central Poland between 1986 and 2016. **Methods**: The fitness of cross-sectional samples of school youth resident in the same 10 communities was evaluated in 4 decennial surveys: 1986—1417 boys/1326 girls; 1996—979 boys/947 girls; 2006—871 boys/843 girls; and 2016—1189 boys/1105 girls. Five tests evaluated speed (5-m run), agility (figure 8 run), explosive power (vertical jump), flexibility (stand and reach), and cardiovascular fitness (modified Harvard step test). Age- and sex-specific descriptive statistics were calculated by survey, while differences among surveys were compared in 3 broad age groups (7–9, 10–12, and 13–15 y) using analysis of variance with age and age squared as covariates. **Results**: Speed and flexibility declined, while the jump and step test index changed variably across surveys. Although agility improved across surveys, the major improvement occurred between 1986 and 1996. **Conclusions**: Performances of rural school youth on 5 tests of physical fitness changed significantly, but, variably, between 1986 and 2016. The results were generally consistent with other studies of Polish school youth that spanned a similar interval.

Keywords: health, pediatrics, physical performance

Interest in changes in the physical performance and fitness of school age youth over time has a long tradition,[1,2] which has increased more recently in the era of systematic reviews.[3,4] This tradition continues in many countries, although time intervals and fitness items considered vary.[5–10]

Given current concerns for the health-related fitness of youth and potential associations with health status in adulthood,[11] cardiovascular endurance and flexibility are often the focus of attention. Performance-related fitness as apparent in tests of speed, agility, and power are central to physical activity in its many forms among youth. Moreover, a physically active lifestyle during youth that includes sufficient levels of moderate and vigorous physical activity is generally accepted as a health promotion and disease prevention strategy.[12] The fitness and activity of youth also have the potential to impact quality of life that may persist into adulthood.

Surveys of the physical fitness in national samples of Polish youth 7–19 years date back to 1932,[13] while the fitness of youth in the city of Cracow was first surveyed in 1938.[14] Both surveys were done during the interval between 1918, when Poland regained its independence, and 1939, when World War II began with the invasion of Poland by Germany. Subsequent national surveys of youth fitness in 1951, 1966, and 1979[15,16] spanned the interval of postwar communist control, while comparisons of prewar and postwar fitness levels in several tests indicated negligible changes between 1932 and 1951 in national samples[15] and inconsistent changes between 1938 and 1962 in Cracow boys.[14]

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With the collapse of the communist government beginning in the 1980s, Poland gradually transitioned to a democratic system in 1989 which was formally established in 1991. At the time of the transition, school attendance was mandatory for children 6–18 years; physical education was compulsory at 2 hours per week. The requirement was increased to 3 hours per week in 1997 and to 4 hours per week in 2002.[17] Concern for youth fitness also continued with national surveys in 1989, 1996, 1999, and 2009.[18–20] In addition, surveys spanning different time intervals were also conducted in specific regions of the country, for example, 4 decennial surveys spanning 1965 and 1995 were conducted in southwestern Poland.[21] Surveys of youth fitness in other regions spanned variable intervals, for example, in the north central region in 1971 and 1991,[22] the southeastern region in 1977 and 1987,[23] in the eastern provinces in 1986 and 2016,[24,25] and in the southwestern region in 2001–2002 and 2010–2011.[26]

The early surveys focused largely on speed, strength, and power, while more recent surveys shifted to international fitness batteries, for example, the International Committee for the Standardization of Physical Fitness Test[27] and EUROFIT test battery,[28] in addition to the Cooper test[29] as a measure of cardiovascular endurance. In doing so, the fitness of Polish youth has been placed in the context of the European and international communities.

Overall, performances of Polish youth on fitness tests (speed, power, and strength) were variable across surveys before and after World War II. Allowing for the different tests, fitness levels of Polish youth generally improved in surveys through 1981, but more recently changes in fitness have been variable, and, in many cases declined. Urban–rural contrasts were apparent in several fitness tests in the 1999 national survey,[19] while secular changes in the hs and weights of rural youth were generally less than corresponding changes in national samples between 1989 and 1999.[19]

In the context of the preceding, the purpose of this study is to evaluate secular changes in the physical fitness of school youth 7–15 years, resident in 10 rural communities in west-central Poland across 4 decennial surveys between 1986 and 2016. In contrast to

previous studies in Poland, the present study is unique in that the fitness surveys of school youth were conducted in the same 10 communities across the interval of 30 years which involved major political, economic, and social transitions in Poland.[24,30] Community-specific data addressing local adaptations to the political, economic, and social changes over the 30 years, however, are not available.

Methods

Background

The growth status and physical fitness of youth attending schools in the 10 rural communities located in the Poznań province were initially evaluated in 1986.[31] The communities were selected in cooperation with the provincial Board of Education and Development to represent different regions of the province. The survey was also approved by the respective community authorities. The communities were located ~19 to 75 km from the city of Poznań. Population sizes varied between 4642 and 9850 in 1986, and the region had many state-owned and cooperative farms.[32] According to local records, none of the communities was involved in previous secular trend research.

School youth in the 10 communities were subsequently surveyed in 1996, 2006, and 2016. The 1986 and 1996 surveys were done when the region was an independent province, while the 2006 and 2016 surveys were done after the Poznań province was consolidated with 4 others as the Greater Poland province in 1999.[33]

Sample

The 4 surveys included 4538 boys and 4331 girls who were sorted by survey into single year chronological age (CA) groups with the whole year as the midpoint (7 y = 6.50–7.49, etc). Three boys and 4 girls were <6.5 years, while 79 boys and 107 girls ≥15.50 years were represented only in 2006 and 2016; both groups were excluded. The sample for analysis thus included 8677 school youth 7–15 years: 1417 boys/1326 girls in 1986, 979 boys/947 girls in 1996, 871 boys/843 girls in 2006, and 1189 boys/1105 girls in 2016.

Ethics

The initial survey was approved by the provincial Board of Education and Development and educational authorities of each community; subsequent surveys were approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (KB 907/16 for 2016) and educational authorities of each community. Parents or legal guardians provided written informed consent for their child/children to participate, while children provided assent for their participation.

Fitness Tests

Testing was done by class. The 5 tests were described and demonstrated. A 10-minute standardized warm-up was given prior to testing which was done in the following order:

Speed—The 5-m Run (in Meters per Second). The student was standing at a line 0.5 m from the starting line. At the start command, he/she ran as fast as possible crossing the starting and finish lines and through markers placed 1 m beyond the latter. Time elapsed from crossing the starting and finishing lines was measured (0.001 s) with laser photocells located 0.5 m above ground on each line (PFL-20 Kabid-Zopan, Poland, 1986, 1996, 2006; Witty, Microgate, Italy, 2016). Two trials were given; the better time was retained. Distance covered per second (in meter per second) was calculated.

Explosive Power/Coordination—Vertical Jump (in Centimeters). Standing erect with his/her side to the centimeter scale, the student extended his/her arm upward along the scale; the highest point (standing reach height) was recorded (nearest centimeter). Then from a half squat position, the student was instructed to jump as high as possible using both arms and legs to assist in projecting the body upward. The highest point of the jump indicated by the reach of the fingers was recorded (in centimeters). The difference between standing reach height and jump height was the score. Three trials were given; the best jump was retained.

Flexibility—Stand and Reach With a Forward Bend (in Centimeters). Without shoes, the student was standing with feet together on a box (height = 32 cm, length = 35 cm, width = 45 cm). The measurement scale was 50 cm at the standing surface and values increased downward. The student was instructed to raise their arms, make the deepest forward bend possible, and hold this position for 1 or 2 seconds. The score was recorded (nearest centimeter) as the distance reached. The forward bend was performed twice; the better result was retained.

Agility—Figure 8 Run (in Seconds). Standing at the starting line midway between 2 poles (120 cm) 5 m apart, the student was instructed to run the figure 8 pattern as fast as possible. The pattern was run 3 times, with the first turn to the right. The time to cover the 3 laps was measured with a stopwatch (0.01 s, 1986, CAENAHO B, C.C.C.P./SLAVA, Russia, 1986; Casio HS-80TW Lap Stopwatch, Japan, 1996, 2006, 2016). Two trials were given; the better results were retained.

Cardiovascular Fitness—Modified Harvard Step Test. The student stepped up and down a box 30.0 cm in height at a metronome pace of 30 full steps (up/down) per minute for 5 minutes (300 s).[34,35] After 5 minutes and resting for 1 minute, heart rate was recorded for 60 seconds using an electronic sensor on the second finger in 1986 and 1996 (N-327-5 analog unit) and with an electronic sensor in the earlobe in 2006 and 2016 (AND C812 analog unit with Tester software (Poznań Technical University). A STI was calculated[35]:

$$\mathrm{STI} = \frac{100 \times (\text{working time in seconds})}{5.5 \times \mathrm{p}},$$

where p = pulse rate between first and second minute after completion of the exercise; 5.5 = constant.

As a guide, a step test index >60 = very high, >50.0 and <60 = high; >40.0 and <50 = average; >30.0 and <40 = low; <30.0 = significantly impaired.[34]

Analysis

Descriptive statistics were initially calculated for each survey by sex-specific single year CA groups to illustrate trends over time. To allow for variation in sample sizes among surveys and for more detailed analysis of secular change in the fitness tests, the data for each survey were partitioned into 3 CA groups spanning 7–9 years (middle childhood in both sexes), 10–12 years (transition into

puberty and midpuberty in most girls, transition into puberty in most boys), and 13–15 years (later adolescence in most girls, interval of the growth spurt in most boys). Sex-specific analysis of covariance, with age and age^2 of each student as covariates, were done in each combined CA group to compare fitness tests across the 4 surveys. Post hoc comparisons of each fitness test between specific surveys, with Bonferroni adjustments for multiple comparisons, were evaluated. Effect sizes were estimated as partial-eta squared (η_p^2); the statistic provides an estimate of the strength of the independent variable (secular or decennial changes) on the dependent variable (mean fitness performances across surveys), after controlling for variation due to CA among groups. Guidelines for the interpretation of effect sizes were as follows: 0.1, small; 0.3, moderate, 0.5, high; 0.7, very large; 0.9, extremely large.[36,37] All analyses were done with SPSS for Windows (version 22.0; IBM Corp, Chicago, IL).

Results

Trends Across Surveys

Mean performances on each fitness test by single-year CA groups in each of the 4 surveys are illustrated in Figure 1A–1E. Sample sizes and descriptive statistics for each fitness test by single-year CA groups of boys and girls within survey are summarized in Supplementary Tables S1a–d (available online).

Speed (Figure 1A) improves, on average, with age among boys from 7 to 15 years in all surveys, but it improves from 7 to 12 years in girls, followed by a plateau. On the other hand, speed declines in both boys and girls between 1986 and 1996 and between 1996 and 2006, while changes between 2006 and 2016 are negligible in both sexes.

Agility (Figure 1B) shows a similar age-related pattern as speed in boys and girls, respectively, but it should be noted that a lower time indicates a better performance. Among boys, agility improves from 1986 to 1996, and does not change appreciably in subsequent surveys. No clear trend is apparent among girls, although agility in the 1996 survey is, on average, best at all ages except 14 years.

The vertical jump (Figure 1C) improves, on average, from 7 to 15 years. There is no clear secular pattern in both sexes; although, the performance of boys in 2006 is consistently better than in 1986.

Flexibility (Figure 1D) is best in 1986 and tends to decline across the 4 surveys, more so in boys than girls. Flexibility shows little improvement with age from 7 to 11 years in both sexes (except girls 7 y in 2006), and increases through 14 years.

The step test index (Figure 1E) shows no consistent pattern with age among boys and overlaps across surveys. In contrast, the index declines with age among girls and is best at most ages in 2006.

Comparisons by Combined Age Groups

Results of the analysis of covariance for each of the 3 combined CA group across surveys are summarized in Tables 1 (boys) and 2 (girls). Performances on all tests across the 30-year span differ significantly in each CA group of boys except for the step test (13–15 y) and in each CA group of girls except for the vertical jump (13–15 y). Effects sizes (η_p^2) are moderate for the speed test in both sexes, and generally low for the other fitness items in both sexes. The significance of post hoc pairwise comparisons vary by test, and is especially apparent in differences between adjacent surveys in contrast to overall changes between 1986 and 2016 (Table 3).

Running speed (in meters per second; Figure 2A) declines between 1986 and 2016 in boys and girls. Speed declines significantly ($P < .05$) between 1986 and 1996, more in boys than girls, and, between 1996 and 2006, more in girls than boys. Changes in speed between 2006 and 2016 are negligible.

Agility (Figure 2B) improves (decease in time) significantly between 1986 and 2016, except among girls 10–12 years. Agility improves significantly ($P < .05$) between 1986 and 1996 in boys and girls in the 3 age groups, while changes between 1996 and 2006 and 2006 and 2016 are variable and significant ($P < .05$) only in boys 13–15 years. Among youth 10–12 years, declines in agility between 1996 and 2006 and between 2006 and 2016, though not significant, negate the improvement between 1986 and 1996.

Change in the vertical jump (Figure 2C) between 1986 and 2016 is similar in boys and girls 7–9 and 10–12 years but is considerably larger among boys 13–15 years and negligible among girls 13–15 years. Jumping performances of boys in the 3 age groups increased between 1986 and 1996 ($P < .05$), are variable between 1996 and 2006, and decline between 2006 and 2016 ($P < .05$). After significant gains between 1986 and 1996, vertical jump performances of girls 7–9 and 10–12 years change negligibly or decline between 1996 and 2006 ($P < .05$, 10–12 y) and between 2006 and 2016. Among girls 13–15 years, changes are negligible and not significant between adjacent surveys.

The decline in flexibility (Figure 2D) between 1986 and 2016 is significant in each age group ($P < .05$) and greater in boys than in girls. The declines occur between 1986 and 1996 and between 1996 and 2006 in both boys and girls ($P < .05$ at 7–9 and 10–12 y). Between 2006 and 2016, girls improve in flexibility, though variably among age groups ($P < .05$, at 7–9 y), while boys continue to decline in flexibility ($P < .05$, at 10–12 and 13–15 y).

The step test index (Figure 2E) improves slightly but not significantly in girls 7–9 and 10–12 years, but increases significantly in girls 13–15 years between 1986 and 2016 ($P < .05$). The index declines across the 30-year interval in boys 7–9 and 10–12 years, but is, on average, unchanged among boys 13–15 years. Changes in the step test index vary considerably between adjacent surveys. The index declines in boys ($P < .05$) and girls 7–9 and 10–12 years but increases in boys and girls ($P < .05$) 13–15 years between 1986 and 1996. The index then increases in the 3 age groups of girls ($P < .05$ at 7–9 and 10–12 y) but declines in boys 10–12 and 13–15 years between 1996 and 2006. The index changes insignificantly between 2006 and 2016, but the direction is positive in boys and negative in girls.

Discussion

Changes in the physical fitness status of rural boys and girls across the 4 decennial surveys spanning 1986 through 2016 varied among the 5 tests. Speed (5-m sprint) and flexibility (stand and reach) declined, while power (vertical jump) and step test index (cardiovascular fitness) changed variably. On the other hand, agility (figure of 8 run) improved across the 4 surveys; although, the major improvement occurred between 1986 and 1996. The variable changes in fitness contrasted positive secular changes in height and weight of the rural youth in the 10 communities,[38] and may reflect increases in the BMI and changes in weight status between 2006 and 2016 in the rural school youth.[34] Though relatively low in prevalence, overweight and obesity increased between 2006 and 2016 compared with 1986 and 1996 and was consistent with estimates Polish youth spanning the past 2 generations.[34]

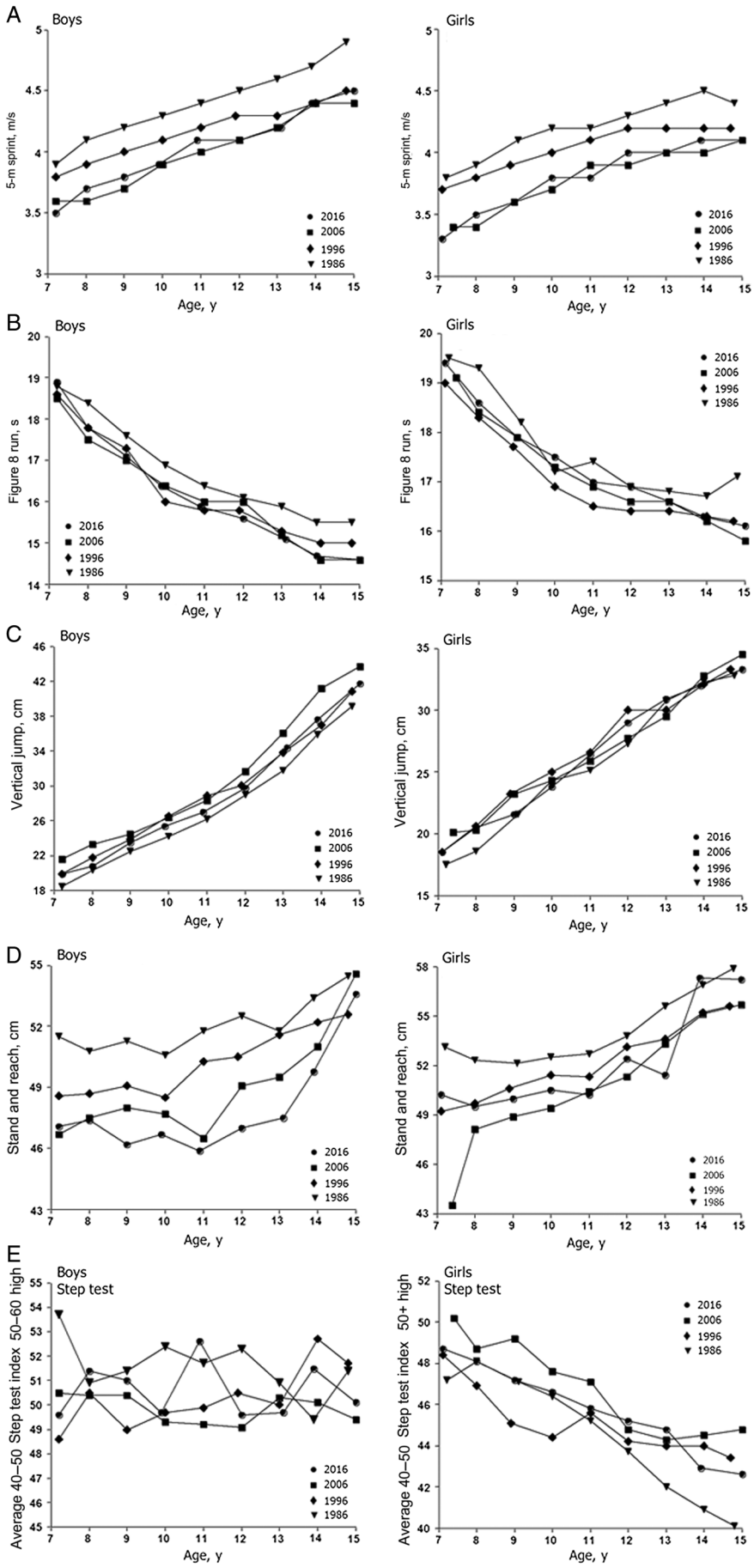

Figure 1 — Mean performances of boys (left) and girls (right) on the 5 fitness tests in each of the decennial surveys.

Table 1 Means and SDs for the 5 Fitness Tests in Boys by Age Group and Year (Speed, 5-m Sprint; Agility, Figure 8 Run; Power, Vertical Jump; Flexibility, Stand and Reach; Cardiovascular, Step Test Index), Results of ANOVA for Age and of ANCOVA With Age and Age^2 as Covariates (F),[a] Age-Adjusted Means and SEs for Each Test, Significant Post Hoc Comparisons, and Partial-Eta Squared (η_p^2)

	Year of survey									Year of survey, age-adjusted mean, and SE								
	1986		1996		2006		2016			1986 (a)		1996 (b)		2006 (c)		2016 (d)		Significant post hoc comparisons***	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE		η_p^2
7–9 y, N	441		272		218		383												
Age, y	8.2	0.7	8.2	0.7	8.2	0.8	8.1	0.8	1.73										
Sprint, m/s	4.1	0.3	3.9	0.3	3.7	0.3	3.7	0.4	199.27**	4.1	0.01	3.9	0.02	3.7	0.02	3.7	0.02	a > d	.31
Figure 8 run, s	18.2	1.9	17.8	1.7	17.5	1.7	17.8	2.3	7.70**	18.2	0.1	17.8	0.1	17.5	0.1	17.8	0.1	c = b = d > a	.02
Jump, cm	20.9	4.6	22.1	4.6	23.4	5.3	21.5	5.1	15.39**	20.8	0.2	22.1	0.3	23.3	0.3	21.6	0.2	c > b > a	.03
Stand and reach, cm	51.1	5.1	48.8	5.3	47.5	5.6	46.9	6.1	44.40**	51.1	0.3	48.8	0.3	47.5	0.4	46.9	0.3	a > b > c = d	.09
Step test index	51.6	8.2	49.6	7.6	50.4	7.5	50.8	8.4	3.58*	51.5	0.4	49.5	0.5	50.4	0.5	50.8	0.4	a > b	<.01
10–12 y, N	552		383		376		422												
Age, y	11.0	0.8	11.0	0.8	11.0	0.9	10.9	0.9	1.19										
Sprint, m/s	4.4	0.3	4.2	0.3	4.0	0.3	4.0	0.3	180.12**	4.4	0.01	4.2	0.01	4.0	0.01	4.0	0.01	a = b > c = d	.24
Figure 8 run, s	16.5	1.5	15.9	1.2	16.1	1.6	16.0	1.6	13.63**	16.5	0.1	15.9	0.1	16.1	0.1	16.0	0.1	b = d = c > a	.02
Jump, cm	26.4	5.7	28.6	5.3	28.9	5.6	27.3	6.3	18.83**	26.4	0.2	28.5	0.3	28.8	0.3	27.4	0.3	c = b > d > a	.03
Stand and reach, cm	51.6	6.0	49.8	6.1	47.8	6.9	46.5	6.3	58.90**	51.6	0.3	49.8	0.3	47.8	0.3	46.5	0.3	a > b > c > d	.09
Step test index	52.1	8.4	50.1	8.0	49.2	7.2	50.6	9.5	9.76**	52.1	0.4	50.0	0.4	49.2	0.4	50.7	0.4	a > d = b = c	.02
13–15 y, N	454		324		277		384												
Age, y	13.8	0.8	13.8	0.7	14.0	0.8	14.0	0.9	9.12*										
Sprint, m/s	4.7	0.3	4.4	0.4	4.3	0.3	4.4	0.3	130.14**	4.7	0.02	4.4	0.02	4.3	0.02	4.4	0.02	a > d = c	.21
Figure 8 run, s	15.6	1.3	15.1	1.0	14.8	1.3	14.8	1.3	40.81**	15.6	0.1	15.1	0.1	14.8	0.1	14.8	0.1	c = d > b > a	.08
Jump, cm	35.1	7.3	36.5	7.0	40.2	8.0	38.0	8.0	25.08**	35.4	0.3	36.9	0.4	40.0	0.4	37.4	0.4	c > b > a, d > a	.05
Stand and reach, cm	53.1	6.7	52.1	6.6	51.6	7.6	50.4	8.0	14.86**	53.3	0.3	52.3	0.4	51.4	0.4	50.0	0.4	a = b > d, b > d	.03
Step test index	50.4	8.6	51.4	8.9	49.9	7.9	50.4	10.2	1.48	50.5	0.4	51.4	0.5	49.9	0.5	50.4	0.5		<.01

Abbreviations: ANOVA, analysis of variance; ANCOVA, analysis of covariance. Note: Higher scores in the sprint and lower scores in the agility run indicate better performances.

[a]The F values refer to the ANOVA comparing chronological age across the 4 surveys and to the ANCOVAs comparing each fitness test across the 4 surveys.

*$P \le .01$. **$P \le .001$. ***Post hoc comparisons $P \le .05$.

Table 2 Means and SDs for the 5 Fitness Tests in Girls by Age Group and Year (Speed, 5-m Sprint; Agility, Figure 8 Run; Power, Vertical Jump; Flexibility, Stand and Reach; Cardiovascular, Step Test Index), Results of ANOVA for Age and of ANCOVA With Age and Age^2 as Covariates (F),[a] Age-Adjusted Means and SEs for Each Test, Significant Post Hoc Comparisons, and Partial-Eta Squared (η_p^2)

	Year of survey									Year of survey, age-adjusted mean, and SE								
	1986		1996		2006		2016			1986 (a)		1996 (b)		2006 (c)		2016 (d)		Significant post hoc comparisons***	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	Mean	SE	Mean	SE	Mean	SE	Mean	SE		η_p^2
7–9 y, N	409		259		219		415												
Age, y	8.3	0.8	8.2	0.7	8.4	0.6	8.1	0.8	7.63**										
Sprint, m/s	3.9	0.3	3.8	0.3	3.5	0.3	3.5	0.3	213.81**	3.9	0.01	3.8	0.02	3.5	0.02	3.5	0.01	d = c > b > a	.33
Figure 8 run, s	18.9	2.0	18.2	1.7	18.2	1.8	18.6	1.9	11.78**	18.9	0.1	18.2	0.1	18.3	0.1	18.5	0.1	b = c = d > a	.03
Jump, cm	19.7	4.5	21.2	4.9	21.6	4.8	20.3	5.5	11.60**	19.5	0.2	21.3	0.3	21.3	0.3	20.6	0.2	b = c = d > a	.03
Stand and reach, cm	52.3	5.5	49.9	6.0	48.0	6.6	49.9	6.9	24.76**	52.3	0.3	50.0	0.4	48.0	0.4	50.0	0.3	a > b = d, b > c	.05
Step test index	47.5	7.7	46.5	7.3	49.1	7.4	48.0	7.4	5.11*	47.6	0.4	46.5	0.5	49.1	0.5	47.9	0.4	c > b	.01
10–12 y, N	505		377		336		391												
Age, y	11.0	0.8	11.0	0.8	11.0	0.8	10.9	0.9	2.07										
Sprint, m/s	4.2	0.3	4.1	0.3	3.8	0.3	3.8	0.3	207.44**	4.2	0.01	4.1	0.02	3.8	0.02	3.8	0.01	d = c > b > a	.28
Figure 8 run, s	17.2	1.6	16.6	1.3	16.9	1.7	17.1	2.1	11.10**	17.2	0.1	16.6	0.1	16.9	0.1	17.1	0.1	b > a = d = c	.02
Jump, cm	25.6	5.2	27.2	5.4	25.9	5.5	26.2	6.2	7.64**	25.5	0.2	27.2	0.3	25.9	0.3	26.3	0.3	b > c > a	.01
Stand and reach, cm	53.0	6.0	51.9	6.0	50.3	6.1	50.9	7.5	14.46**	53.0	0.3	51.9	0.3	50.3	0.3	51.0	0.3	a = b > c, a > d	.03
Step test index	45.1	7.3	44.8	6.8	46.6	7.0	45.9	7.6	4.63*	45.1	0.3	44.8	0.4	46.6	0.4	45.8	0.4	b = a > c	<.01
13–15 y, N	412		311		288		297												
Age, y	13.7	0.7	13.7	0.7	13.9	0.9	13.9	0.9	4.70*										
Sprint, m/s	4.4	0.3	4.2	0.3	4.0	0.3	4.0	0.3	162.61**	4.4	0.01	4.2	0.02	4.0	0.02	4.0	0.02	c = d > b > a	.27
Figure 8 run, s	16.8	1.4	16.3	1.3	16.3	1.4	16.3	1.5	11.42**	16.8	0.1	16.3	0.1	16.3	0.1	16.4	0.1	b = c = d > a	.03
Jump, cm	31.7	5.8	31.5	5.6	32.0	6.0	32.0	6.1	0.24	31.8	0.3	31.6	0.3	31.9	0.3	31.9	0.3		<.01
Stand and reach, cm	56.5	6.4	54.6	6.0	54.6	6.7	55.1	8.0	7.49**	56.6	0.3	54.6	0.4	54.5	0.4	55.0	0.4	a > c = b = d	.02
Step test index	41.2	5.5	43.9	6.2	44.5	5.9	43.5	7.0	20.17**	41.2	0.3	43.9	0.3	44.5	0.4	43.5	0.4	c = b = d > a	.04

Abbreviations: ANOVA, analysis of variance; ANCOVA, analysis of covariance. Note: Higher scores in the sprint and lower scores in the agility run indicate better performances.

[a]The F values refer to the ANOVA comparing chronological age across the 4 surveys and to the ANCOVAs comparing each fitness test across the 4 surveys.

*$P < .01$. **$P < .001$. ***Post hoc comparisons $P \leq .05$.

Table 3 Estimated Secular Changes in Individual Tests of Physical Fitness Across the 30-Year Interval (1986–2016) and Between Adjacent Decennial Surveys in Boys and Girls: Means and SEs Based on Analysis of Covariance With Age and Age^2 as Covariates

		Secular gains/losses							
				Adjacent surveys (per decade)					
		30 y, 1986–2016		1986–1996		1996–2006		2006–2016	
	Age group, y	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Speed—5-m sprint, m/s									
Boys	7–9	–0.43	0.02*	–0.18	0.02*	–0.26	0.03*	0.01	0.02
	10–12	–0.38	0.02*	–0.18	0.02*	–0.21	0.02*	0.01	0.02
	13–15	–0.37	0.02*	–0.3	0.02*	–0.08	0.03*	0.02	0.03
Girls	7–9	–0.42	0.02*	–0.09	0.02*	–0.35	0.03*	0.03	0.02
	10–12	–0.39	0.02*	–0.14	0.02*	–0.27	0.02*	0.02	0.02
	13–15	–0.4	0.02*	–0.21	0.02*	–0.2	0.02*	0.01	0.02
Agility—figure 8 run, s									
Boys	7–9	–0.42	0.13*	–0.42	0.15*	–0.28	0.17	0.28	0.16
	10–12	–0.49	0.10*	–0.57	0.10*	0.23	0.11	–0.15	0.11
	13–15	–0.84	0.09*	–0.52	0.09*	–0.29	0.10*	–0.03	0.1
Girls	7–9	–0.46	0.13*	–0.77	0.14*	0.13	0.17	0.18	0.15
	10–12	–0.02	0.11	–0.58	0.11*	0.33	0.13	0.23	0.12
	13–15	–0.44	0.11*	–0.49	0.11*	–0.04	0.11	0.09	0.12
Power—vertical jump, cm									
Boys	7–9	0.82	0.33	1.33	0.36*	1.19	0.42*	–1.71	0.39*
	10–12	1.05	0.35*	2.1	0.36*	0.35	0.39	–1.4	0.38*
	13–15	1.99	0.48*	1.47	0.50*	3.09	0.57*	–2.57	0.55*
Girls	7–9	1.06	0.33*	1.76	0.37*	0.04	0.43	–0.74	0.4
	10–12	0.91	0.36	1.65	0.36*	–1.23	0.39*	0.48	0.38
	13–15	0	0.44	–0.29	0.43	0.36	0.47	–0.06	0.47
Flexibility—stand and reach, cm									
Boys	7–9	–4.22	0.39*	–2.29	0.43*	–1.3	0.51*	–0.62	0.47
	10–12	–5.11	0.41*	–1.8	0.42*	–2.08	0.46*	–1.23	0.45*
	13–15	–3.22	0.49*	–0.95	0.51	–0.87	0.58	–1.4	0.56
Girls	7–9	–2.46	0.44*	–2.38	0.50*	–1.93	0.58*	1.85	0.53*
	10–12	–2.03	0.43*	–1.12	0.43	–1.59	0.47*	0.68	0.47
	13–15	–1.56	0.51*	–1.93	0.50*	–0.1	0.54	0.47	0.55
Cardiovascular—step test index									
Boys	7–9	–0.75	0.56	–1.99	0.62*	0.89	0.73	0.36	0.68
	10–12	–1.44	0.55*	–2.1	0.56*	–0.78	0.61	1.44	0.59
	13–15	–0.08	0.63	0.96	0.66	–1.49	0.74	0.44	0.71
Girls	7–9	0.35	0.52	–1.08	0.59	2.64	0.69*	–1.22	0.63
	10–12	0.73	0.48	–0.3	0.49	1.79	0.53*	–0.76	0.53
	13–15	2.32	0.47*	2.66	0.46*	0.65	0.5	–0.99	0.51

*$P < .05$.

Trends in the fitness of rural school youth in the 10 communities were generally consistent with other surveys in Poland that spanned all or part the interval considered in the present study. In national samples, for example, the Cooper test, strength, and standing long jump declined or did not change across surveys in 1979, 1989, and 1999.[39] Regionally, speed, endurance, strength, and agility (lesser extent) declined between 1965 and 1995 among youth in Upper Silesia (southwestern Poland).[21] Power, speed, and agility improved while agility declined between 1971 and 1981 in youth from the Bydgoszcz region (north central), but all fitness items declined between 1981 and 1991.[22] Among school youth in eastern Poland, several indicators of fitness declined between 1986 and 2006,[24] and between 1986 and 2016.[25] Among urban Cracow youth, sit-ups, the standing long jump, and sit and reach performances declined between 1980s and 2000,[40] while the overhead medicine ball throw and standing long jump changed variably between 1975–1980 and 2005–2010 in youth from Cracow and a small town and village.[23]

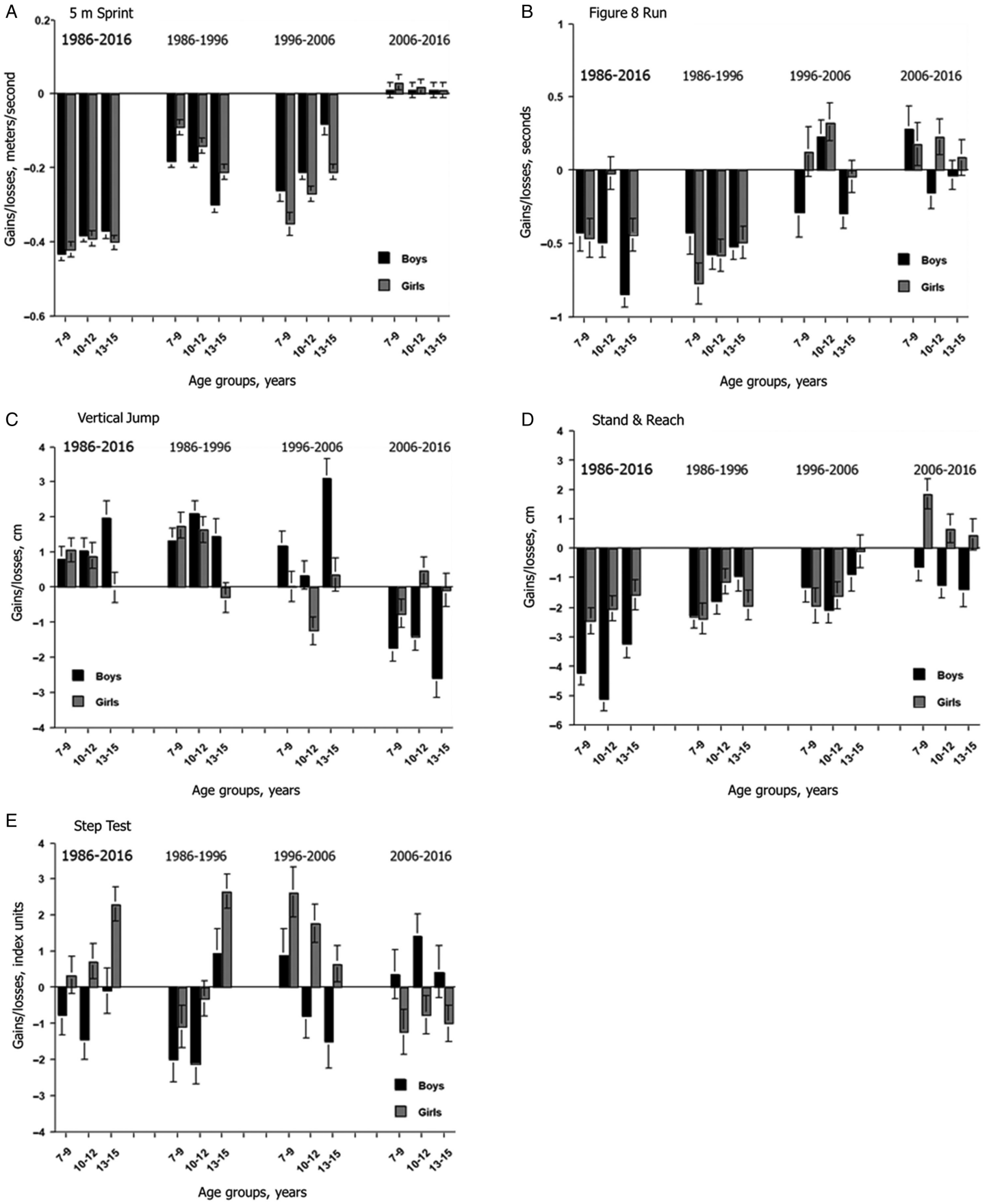

Figure 2 — Age-adjusted mean differences and standard errors in the 5 fitness tests (based on sex-specific ANCOVAs with age and age^2 as covariates) among boys and girls in 3 age groups (7–9, 10–12 and 13–15 years) between 1986 and 2016 (30 years) and between adjacent decennial surveys (1986–1996, 1996–2006, 2006–2016).

Trends noted among Polish youth were generally consistent with trends in other countries.[3,5]

Secular changes in the growth of Polish children and youth have been generally interpreted in the context of the major political, economic, and social changes which have occurred in the country beginning the 1980s.[14,19,22,24,25,38] The changes included major strikes and political unrest, imposition of martial law, and eventual collapse of the communist government, which was followed by democratic elections late in 1991. Since then, economic conditions have been rather variable.

It is difficult to evaluate the changes in youth fitness in the context of the economic and social changes associated with the government transition in the 1980s and subsequent years. It is reasonable to assume, however, that the changes influenced education. Physical education which was compulsory at 2 hours per week was increased to 3 hours per week in 1997 and to 4 hours per week in 2002. Of the latter requirement, 3 hours per week of school physical education were mandatory, while the fourth hour was optional and dependent upon local opportunities outside of the school setting, for example, swimming classes, running in the forests, skiing, and so forth.[17,41] Assessment in physical education was expanded to include basic motor skills and coordination in addition physical fitness. Over time, assessment of motor skills and fitness was increasingly placed in the context of physical activity with the goal of preparing school youth for lifelong physical activity.[42]

Implementation of the changes in physical education, however, varied considerably despite detailed evaluation programs and systems. A national audit in 2010 indicated several irregularities.[43] Between 2007 and 2009, for example, the physical education curriculum in more than one-half of schools in Poland was not modified to meet government regulations, while the new core curriculum for 2009–2010 was not implemented in 20% of schools. Of relevance to the present discussion, the national audit noted that two-thirds of schools did not monitor student progress in physical education, including fitness testing. It was also estimated that 20% to 40% of school youth participated in fewer physical education classes and physical activities than required by law, and the trend increased with the age of students.[44]

With the preceding as background, it is important to consider the fitness of Polish youth in the context of physical activity and inactivity, both of which are established independent correlates of physical fitness. Data on the activity habits of Polish youth in the 1980s are lacking, while national data suggested a decline in vigorous and MVPA among adolescents since 1990. Percentages of boys 11, 13, and 15 years reporting vigorous physical activity 4 to 7 days per week in the 1990s were 54%, 51%, and 42%, respectively, and declined in 2018 to 43%, 37%, and 35%. Corresponding estimates among girls were lower and changed negligibly between the 1990s and 2018 in the 3 age groups, respectively, 38%, 31%,and 20% to 36%, 27%, and 22%. With a modified indicator of MVPA, including mandatory school physical education (4 h/wk since 2002), percentages of Polish boys reporting MVPA 7 days per week in 5 surveys spanning 2002 to 2018 varied between 24% to 34% at 11 years, 16% to 29% at 13 years and 16% to 25% at 15 years. Percentages of girls reporting MVPA 7 days per week across the interval were 18% to 27% at 11 years, 12% to 18% at 13 years, and 8% to 11% at 15 years.[45–47] From a more general perspective, the 2018 Physical Activity Fact Sheet for Poland[48] noted that only 19% of girls and 30% of boys 11–15 years had a level of activity sufficient for health and fitness, while the 2018 Physical Activity Report Card for Poland[49] concluded that few Polish children and youth meet recommended activity levels.

Declines in physical activity were accompanied by an increase in sedentary activities. Allowing for slight variation across surveys spanning 2000 and 2018, >50% Polish youth 11 to 15 years spent ≥2 to 3 hours per day watching TV/videos on school days, with more doing so on the weekend. Percentages of youth spending ≥2 to 3 hours per day at computer games were relatively low on school days, especially among girls, but 46% to 58% of boys 13–15 years reported 4+ hours playing computer games on weekends with little variation across surveys.[45–47] In an independent survey in 2011, >50% of Polish middle and high school youth spent ≥3 hours per day watching TV or on the computer.[45]

Changes in diet over time may influence weight status, which is a potential correlate of fitness especially at the upper extremes of the BMI. During the 1980s and 1990s, discussions of diet in Poland in the 1980s and 1990s were generally focused on dietary adequacy for growth and health, and the potential need for food rationing.[50] Nevertheless, the estimated consumption of calories and nutrients of school youth 13–15 years in the city of Poznań did not differ between 1980 and 1990.[51] Subsequently, a survey of eating habits of Polish adolescents suggested increased consumption of processed and "fast foods" between 1990 and 2000.[52] Although rural adolescents in Poland consumed fewer calories than urban peers, increased energy from fat and decreased energy from carbohydrates and proteins were noted in both groups.[44] More recently, percentages of Polish youth 13–15 years consuming sweets and sweet drinks increased more than 3-fold between 2002 and 2018, 18.1% to 69.9% and 12.7% to 44.9%, respectively.[45–47]

The preceding trends indicated increased inactivity and decreased physical activity among Polish adolescents in addition to relatively recent changes in the diet, specifically processed and "fast foods," and sweet drinks. Corresponding estimates for younger school children are not available. Although studies directly relating diet, inactivity, and physical activity to levels of fitness among Polish youth are lacking, reduced levels of physical fitness may present health risks for youth.[12,53] The recent changes in diet, inactivity, and activity are also relevant to the increased prevalence of overweight and obesity among the present and other samples of Polish youth since the mid-1990s, more so among children compared with adolescents.[54] Overweight and especially obesity generally have a negative influence on indicators of fitness among youth, specifically tests that require movement or projection of the body.[2,55,56] Relationships between the BMI and the fitness tests in the present samples of Polish youth over time were generally low and did not show consistent quadratic relationships[54] The latter likely reflected the relatively large concentrations of the BMIs of the rural boys and girls in the normal weight range.[54]

Conclusions

Secular changes in several indicators of the physical fitness of rural school youth in west-central Poland between 1986 and 2016, though significant, were variable but generally consistent with other surveys in the country. The trends were generally consistent with declines in physical activity and increases in physical inactivity of Polish youth since the 1990s. Changes in diet associated with fast foods and sweet drinks are related considerations.

The study is unique in that school youth in the same 10 communities were surveyed on 4 occasions. However, the lack of an indicator of maturity status and of information on physical activity and dietary habits in the 10 communities over time was a major limitation.

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WEIGHT STATUS, BMI AND PHYSICAL FITNESS IN POLISH YOUTH: RELATIONSHIPS BETWEEN 1986 AND 2016

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Abstract

Background: One of the components affecting the level of health is physical fitness and diets, which is also considered the foundation of a healthy lifestyle. **Methods:** Samples by survey ranged from 871 to 1,417 (boys) and from 843 to 1,326 (girls). Speed (5 m run), agility (figure-8-run), explosive power (vertical jump), flexibility (stand and reach) and cardiovascular fitness (step test) were measured. The Body Mass Index (BMI) of each student was classified as Thin, Normal weight or Overweight/Obese (Owt/Ob) relative to International Obesity Task Force (IOTF) criteria. Fitness items were compared among weight status groups and across surveys with sex-specific analyses of covariance. Regressions of each fitness item on the BMI in the four surveys were done using linear and nonlinear quadratic models. **Results:** Performances on all fitness tests except flexibility were poorer among Owt/Ob compared to Normal and Thin youth, but performances on fitness tests within weight status groups did not differ consistently across surveys. **Conclusions:** Relationships between the BMI and fitness tests varied across surveys, but suggested reasonably consistent cur-vilinear relationships between fitness tests and the BMI among boys more so than girls.

Keywords*: overweight; obesity; thinness; step test, speed; vertical jump*

Introduction

The lifestyle changes associated with diets of fast foods, reduced physical activity and increased sedentary behaviors (physical inactivity) are often indicated as major factors associated with the increasing prevalence of overweight and obesity among children and adolescents (Hu, 2011; Lobstein et al., 2004). Reduced habitual physical activity and increased sedentary time are also associated with declines in physical fitness, while overweight and obesity are specifically associated with reduced levels of fitness, especially items which require the projection or movement of the body as in jumps and runs (Arnaoutis et al., 2018; Chwałczyńska et al., 2017; Fairchild et al., 2016; Huang & Malina, 2007; Lopes et al., 2012). Reduced body mass reflected in a low Body Mass Index (BMI) may also negatively influence fitness, but studies addressing the relationship between thinness and fitness are relatively limited (Bovet et al., 2007; Xu et al., 2020).

Several studies have considered relationships between fitness across the total spectrum of the BMI among children and adolescence. Results generally suggest a curvilinear relationship; children and youth with a normal BMI tend to have better results in several fitness items compared to those with a low or high BMI (Huang & Malina, 2007, 2010; Kwieciński et al., 2018; Lopes et al., 2019; Zenić et al., 2013). Exceptions to the trends are tests of the flexed arm hang in which thin children and youth generally perform better (Artero et al., 2010; Monyeki et al., 2012), and some endurance items in which thin children and youth tended to perform at higher level (Xu et al., 2020).

In the context of the preceding, the purpose of the present study is twofold: first, to compare the fitness of Thin, Normal weight and Overweight/Obese youth 7-15 years of age across four surveys spanning 1986 through 2006, and second, to evaluate relationships between each fitness item and the BMI in the four surveys. A curvilinear relationship between the BMI and fitness test performances is hypothesized.

Methods

The growth status and physical fitness of children and adolescents attending schools in ten rural communities in the province of Poznań was evaluated in the 1985/1986 school year (Strzelczyk, 1995). The communities were selected in cooperation with the provincial Board of Education and Development in Poznań to represent different regions of the province. Population sizes varied between 4642 and 9850. School youth in the ten communities were surveyed again in 1996, 2006 and 2016 (Bartkowiak, et al., 2021a). The communities were not involved in previous secular trend research in Poland.

Ethics

The initial survey was approved by the provincial Board of Education and Development and educational authorities of each community, while subsequent surveys were approved by the Human Ethics Research Committee of the Karol Marcinkowski Medical University in Poznań (907/16 for 2016) and educational authorities of each community. Parents/legal guardians provided written informed consent, and the youth provided assent for their participation. The surveys were conducted by faculty and staff of the University of Physical Education in Poznań with the assistance of teachers at each school.

Sample

Numbers of school youth 7-15 years across surveys were 1,417 boys and 1,326 girls in 1986, 979 boys and 947 girls in 1996, 871 boys and 843 girls in 2006, and 1,189 boys and 1,105 girls in 2016.

Weight Status

Height (0.1 cm) and weight (0.1 kg) were measured during the school day in the gymnasium of each community (Bartkowiak et al., 2021a). The BMI (kg/m^2) was used to classify each student as severely, moderately or mildly thin, normal weight, overweight or obese using age- and sex-specific IOTF cut-offs (Cole et al., 2000, 2007). Numbers of severely and moderately thin and of obese youth were relatively limited (Bartkowiak et al., 2021c). The former were thus combined with mildly thin youth into a single group (Thin), while the latter were combined with overweight youth into a single group (Owt/Ob).

Fitness

Five tests of physical fitness were administered in each survey. Details of the tests, each of which evaluated a specific component of fitness, have been previously described (Bartkowiak et al., 2021c). The tests were administered in the following order: speed - 5-meter run [m/s]; explosive power - vertical jump [cm]; flexibility - stand and reach with a forward bend [cm]; agility - figure-of-eight run [s]; and cardiovascular (CV) fitness – modified Harvard step test expressed as an index [pts].

Analysis

To account for variable numbers of subjects by single year CA groups, boys and girls in each survey were respectively combined into three CA groups for analysis: (1) 7-9 years (6.50-9.49 years) - middle childhood in both sexes; (2) 10-12 years (9.50-12.49 years) - transition into puberty and mid-puberty (most girls) and transition into puberty (most boys); and (3) 13-15 years (12.50-15.49 years) - late adolescence (most girls) and the interval of the growth spurt (most boys). Sex-specific analyses were done in each CA group.

First, performances on each fitness test were compared among Thin, Normal weight and Owt/Ob youth within and among surveys using analysis of covariance (ANCOVA) with age and age^2 as covariates. The covariates adjust for potential linear and non-linear effects in CA distributions. Second, sex-specific regressions of each fitness test on the BMI were done by survey using linear and nonlinear quadratic models. The test was the dependent variable; the BMI was the independent variable in the linear model, while the BMI and BMI^2 were independent variables in the quadratic model. With the linear model,

$$\text{fitness item} = a + b*BMI;$$

and with the nonlinear quadratic model,

$$\text{fitness item} = a + b*BMI + c*BMI^2$$

where a (intercept), b (linear coefficient), and c (non-linear coefficient) are constants.

Results

Results of the ANCOVAs are summarized in Table 1. Fitness test performances differ significantly among the three weight status groups of boys and girls, with the exception of flexibility among boys 7-9 years and boys and girls 10-12 years. Performances also differ significantly among surveys except for CV fitness among boys 7-9 and 13-15 years and explosive power among girls 13-15 years. However, interactions between weight status and year of survey are not consistently different and show no clear pattern among fitness test in both sexes.

Age-adjusted means, standard errors, 95% confidence intervals and significant post-hoc comparisons between weight status groups within survey (year) and between surveys within weight status group for each fitness test by age group are summarized in Tables 2 (boys) and 3 (girls). Of note, a lower time in the agility test indicates a better performance, while higher scores in the other tests indicate better performances.

Table 1. Results (F values and eta^2 [η_p^2]) of sex and age group specific univariate analyses of covariance (age, age^2 as covariates) of the influence of weight status (thin, normal, owt/ob) and year (1986, 1996, 2006, 2016), and their interactions for each fitness test

	BOYS						GIRLS					
	Weight Status		Year		Wt St x Year		Weight Status		Year		Wt St x Year	
7-9 yrs	F	ηp2	F	ηp2	F	ηp2	F	ηp2	F	ηp2	F	ηp2
Speed	21.15***	0.03	75.50**	0.15	1.45	0.01	12.21***	0.02	122.01***	0.22	1.35	0.01
Agility	5.62**	0.01	7.71***	0.02	2.08*	0.01	3.64*	0.01	3.81**	0.01	1.34	0.01
Power†	18.87***	0.03	5.38**	0.01	0.27	0.00	10.81***	0.02	4.60**	0.01	3.27**	0.02
Flexibility	0.68	0.00	26.16***	0.06	2.34*	0.01	4.17**	0.01	18.38***	0.04	2.41*	0.01
CV Fitness	12.27***	0.02	0.03	0.00	1.75	0.01	8.03***	0.01	4.79**	0.01	2.27*	0.01
10-12 yrs												
Speed	58.63***	0.07	64.62***	0.10	0.66	0.00	38.73***	0.05	105.11***	0.17	2.40*	0.01
Agility	31.13***	0.04	7.56***	0.01	0.33	0.00	13.35***	0.02	9.66***	0.02	1.08	0.00
Power†	67.17***	0.07	13.46***	0.02	0.91	0.00	40.39***	0.05	6.57***	0.01	2.10*	0.01
Flexibility	0.20	0.00	29.98***	0.05	1.72	0.01	1.39	0.00	8.19***	0.02	1.28	0.01
CV Fitness	35.67***	0.04	4.18**	0.01	1.84	0.01	6.36**	0.01	3.96**	0.01	1.19	0.00
13-15 yrs												
Speed	32.95***	0.04	53.75***	0.10	0.49	0.00	31.35***	0.05	75.07***	0.15	0.95	0.00
Agility	36.23***	0.05	15.45***	0.03	2.72*	0.01	12.85***	0.02	3.77**	0.01	1.69	0.01
Power†	28.05***	0.04	14.59***	0.03	1.96	0.01	30.45***	0.05	0.73	0.00	0.57	0.00
Flexibility	13.29***	0.02	11.36***	0.02	1.32	0.01	7.96***	0.01	3.50*	0.01	1.05	0.01
CV Fitness	20.41***	0.03	0.38	0.00	0.53	0.00	7.39***	0.01	15.11***	0.03	2.71*	0.01

*p≤0.05, **p≤0.01, ***p≤0.001, † - Explosive Power

Although not consistent for all comparisons, post hoc comparisons suggest poorer performances on all fitness tests except flexibility among Owt/Ob compared to Normal and Thin boys (Table 2). Comparisons of fitness performances within weight status groups across surveys, however, are variable except for speed. Running speed is generally similar between 1986 and 1996 and between 2006 and 2016, but is significantly better in 1986 and 1996 compared to 2006 and 2016. CV fitness is also better in the two younger age groups in 1986.

Corresponding post hoc comparisons among girls, indicate consistently poorer performances in explosive power among Owt/Ob girls 10-12 and 13-15 years, while performances of Thin and Normal girls do not consistently differ (Table 3). Running speed in girls shows a pattern that is similar to that in boys, i.e., similar performances 1986 and 1996 and in 2006 and 2016, but significantly better performances in 1986 and 1996 compared to 2006 and 2016. Performances on the other fitness tests within weight status groups are, as in boys, variable across surveys and show no consistent trends.
Results of the regression analyses are summarized in Tables 4 (boys) and 5 (girls).

Most of the regressions have a very low explained variance (R^2) and several are not significant. Relationships between the BMI and fitness performances also vary across the four surveys. Nevertheless, the quadratic coefficients are significant in some models, indicating that the association between the BMI and the specific fitness test is curvilinear. This suggests that better performances are generally attained by youth with BMIs in the mid-range of the distribution, while performances of those at the low and high tails of the BMI distribution are lower. This is apparent for relationships between the BMI and speed, agility and explosive power in the 1986 survey except among girls 7-9 years. On the other hand, a curvilinear relationship is suggested across the four surveys for all tests except CV fitness among boys 13-15 years. Though significant, the explained variances are low. Note, however, that the standardized regression coefficient should vary between -1 and 1, but values < -1 and > 1 may occur when there is collinearity between the independent variables. The latter often occurs when the model includes x and x^2. Overall, the hypothesis of a curvilinear association between the BMI and fitness test performances was partially supported.

Discussion

Comparison among weight status groups indicated, on average, poorer performances on all fitness tests except flexibility among Owt/Ob compared to Normal and Thin boys and girls. On the other hand, performances on the five fitness tests were generally similar within the samples of Thin, Normal weight and Owt/Ob youth across the four surveys. By inference, there were no consistent secular trends in fitness performances within weight status groups.
Results of the regression analyses were quite variable (Tables 4 and 5) and likely reflected the concentration of the sample within the normal weight range with proportionally fewer youth at the extremes of the BMI distributions. At the low end of the BMI range, the prevalence of severe and moderate thinness was very low across the four surveys in both boys and girls, while the prevalence of mild thinness was relatively low in all surveys except among boys and girls 7-9 years in 1986. On the other hand, the prevalence of overweight was higher in 2006 and 2016 compared to 1986 and 1996 among boys and girls in the three age groups, while the prevalence of obesity was low (Bartkowiak et al., 2021b). The relatively low prevalence at both extremes of the BMI distributions in the three age groups translated into a limited range of BMIs, which likely influenced the relationships between the BMI and each fitness test and in turn the quadratic regressions.

Nevertheless, results of the regression analyses in the present study were reasonably consistent with trends suggested in the literature. For example, results for the rural youth 13-15 years in 2006 and 2016 were generally consistent with a similar analysis of relationships between the BMI and fitness among school youth 13-15 years resident in an urban-rural administrative district about 110-120 km east-southeast of Poznań (Kwieciński et al., 2018). Although different fitness tests were used, the results were consistent in showing curvilinear relationships with the BMI for tests of speed (50 m dash, 5 m sprint), agility (shuttle run, figure-8-run), and explosive power (standing long jump, vertical jump) in both sexes. For flexibility (standing forward bend/reach), results were curvilinear in boys and linear in girls in both studies. In contrast, results varied for the tests of cardiovascular endurance, 1000 m (boys) and 800 m (girls) runs compared to the step test (present study).

A curvilinear relationship was noted for the vertical jump in the rural Polish school youth in the three age groups in 1996 and for the standing long jump in a 1997 national sample of Taiwan girls 9-10, 11-12 and 13-15 years and boys 11-12 and 13-15 years of age (Huang and Malina, 2010), the relationship was linear among Taiwan boys 9-10 years. For CV fitness, curvilinear relationships were noted for the 800 (girls) and 1600 (boys) meter run-walk in Taiwan youth and for the step test in Polish youth 13-15 years. Linear relationships in both studies were noted for the 800 meter run-walk in Taiwan youth 9-10 years and for the step test in Polish youth 7-9 years, while results were variable among Taiwan youth 11-12 years and Polish youth 10-12 years. On the other hand, results in the two studies varied for flexibility, curvilinear for the sit and reach for Taiwan boys and girls, but variable for the stand and reach in Polish youth.

Table 2. Age-adjusted means (M) and standard errors (SE) based on age-group specific ANCOVAs (age, age^2 as covariates) and significant post hoc comparisons (SPHC, $p<0.05$) between weight status groups within survey (right column) and between surveys within weight status group (horizontal) for each fitness test among BOYS.

Speed – 5 m dash (m/s)

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	4.0	0.3	3.97-4.09	4.1	0.2	4.10-4.17	3.9	0.5	3.83-4.01	N>T=O
	1996	3.9	0.7	3.73-3.99	3.9	0.2	3.90-3.97	3.8	0.5	3.75-3.94	
	2006	3.6	0.9	3.46-3.81	3.7	0.2	3.65-3.74	3.6	0.4	3.50-3.65	
	2016	3.7	0.4	3.65-3.82	3.7	0.2	3.67-3.74	3.5	0.3	3.49-3.60	T=N>O
	SPHC			86>06=16			86>96>06=16			86=96>06=16	
10-12 yrs	1986	4.4	0.4	4.31-4.47	4.4	0.1	4.38-4.44	4.2	0.4	4.08-4.23	T=N>O
	1996	4.3	0.5	4.18-4.35	4.2	0.2	4.19-4.26	4.0	0.4	3.94-4.10	T=N>O
	2006	4.1	0.5	3.95-4.15	4.0	0.2	4.01-4.08	3.8	0.3	3.78-3.90	T=N>O
	2016	4.1	0.5	3.98-4.18	4.0	0.2	4.01-4.08	3.9	0.3	3.83-3.93	T=N>O
	SPHC			86>06=16			86>96>06=16			86>06=16	
13-15 yrs	1986	4.7	0.5	4.59-4.77	4.7	0.2	4.72-4.78	4.6	0.5	4.47-4.65	N>O
	1996	4.4	0.5	4.33-4.53	4.5	0.2	4.41-4.53	4.2	0.5	4.15-4.34	N>O
	2006	4.2	0.6	4.12-4.36	4.4	0.2	4.34-4.42	4.2	0.4	4.13-4.31	N>O
	2016	4.3	0.6	4.22-4.44	4.4	0.2	4.38-4.45	4.2	0.3	4.15-4.28	N>O
	SPHC			86>06=16			86>96=06=16			86>96=06=16	

Agility – figure-of-eight run (s)†

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	18.7	0.2	18.3-19.2	18.0	0.1	17.8-18.2	18.5	0.3	17.9-19.1	N>O=T
	1996	18.4	0.4	17.5-19.3	17.7	0.1	17.4-17.9	18.3	0.3	17.7-19.0	
	2006	16.8	0.6	15.7-17.9	17.5	0.1	17.2-17.8	17.7	0.3	17.3-18.2	
	2016	17.4	0.3	16.8-17.9	17.7	0.1	17.5-17.9	18.3	0.2	18.0-18.7	T=N>O
	SPHC			06=16>86							
10-12 yrs	1986	16.3	0.2	15.9-16.7	16.4	0.7	16.3-16.5	17.1	0.2	16.7-19.1	T=N>O
	1996	16.0	0.2	15.5-16.4	15.8	0.8	15.6-16.0	16.5	0.2	16.1-16.9	N>O
	2006	16.0	0.3	15.5-16.5	15.9	0.9	15.7-16.1	16.8	0.2	16.5-17.1	N=T>O
	2016	15.6	0.3	15.1-16.1	15.8	0.9	15.6-16.0	16.6	0.1	16.3-16.8	T=N>O
	SPHC			86>96=06=16							
13-15 yrs	1986	15.4	0.2	15.1-15.8	15.6	0.1	15.5-15.7	16.2	0.2	15.8-16.6	T=N>O
	1996	15.1	0.2	14.7-15.5	15.0	0.1	14.9-15.2	15.6	0.2	15.2-15.9	N>O
	2006	14.4	0.2	13.9-14.8	14.7	0.1	14.5-14.8	15.7	0.2	15.4-16.1	T=N>O
	2016	15.2	0.2	14.8-15.6	14.5	0.1	14.4-14.7	15.4	0.1	15.2-15.7	N>T=O
	SPHC			86>06			86>96>06=16			86>16	

Explosive Power – vertical jump (cm)

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	20.2	0.5	19.2-21.2	21.1	0.3	20.6-21.6	19.2	0.8	17.7-20.7	
	1996	20.4	1.1	18.2-22.5	22.5	0.3	21.9-23.1	20.4	0.8	18.8-21.9	
	2006	22.1	1.4	19.3-25.0	24.0	0.4	23.2-24.7	21.8	0.6	20.5-23.0	N>O
	2016	21.5	0.7	20.1-22.9	22.3	0.3	21.8-22.9	20.0	0.5	19.1-20.9	
	SPHC						06>96=16=86				
10-12 yrs	1986	27.6	0.7	26.2-29.1	26.8	0.3	26.3-27.3	22.2	0.7	20.8-23.6	T=N>O
	1996	28.9	0.8	27.3-30.5	29.0	0.3	28.4-29.6	25.0	0.8	23.5-26.5	N=N>O
	2006	30.1	0.9	28.3-31.9	29.5	0.3	28.9-30.2	26.2	0.6	25.1-27.3	T=N>O
	2016	30.7	0.9	28.9-32.6	28.3	0.3	27.6-28.9	24.6	0.5	23.6-25.5	T=N>O

	SPHC					86<96=06				86<06		
13-15 yrs	1986	35.0	1.0	33.0-37.0	35.9	0.4	35.2-36.6	31.5	1.1	29.5-33.6		N>O
	1996	35.3	1.1	33.1-37.6	37.6	0.4	36.7-38.4	34.4	1.0	32.4-36.4		N>O
	2006	38.2	1.4	35.5-40.9	40.5	0.5	39.5-41.4	39.0	1.0	37.0-40.9		
	2016	35.3	1.3	32.8-37.7	39.1	0.4	38.2-39.9	33.6	0.7	32.2-35.0		N>T=O
	SPHC					86<96<06=16				86=96<06		
Flexibility – forward bend (cm)												
				Thin (T)			Normal (N)			Owt/Ob (O)		
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC	
7-9 yrs	1986	50.7	0.6	49.5-51.9	51.1	0.3	50.5-51.7	52.3	0.9	50.5-54.1		
	1996	48.5	1.3	45.9-51.1	48.8	0.4	48.1-49.5	49.3	1.0	47.4-51.2		
	2006	47.8	1.8	44.4-51.3	47.0	0.4	46.1-47.9	49.0	0.8	47.5-50.5		
	2016	47.1	0.9	45.4-48.8	47.4	0.4	46.7-48.1	45.7	0.6	44.6-46.8		
	SPHC			86>16			86>96=16=06			86>16		
10-12 yrs	1986	50.9	0.9	49.1-52.6	51.5	0.3	50.9-52.1	53.0	0.9	51.3-54.7		
	1996	49.7	1.0	47.7-51.6	49.8	0.4	49.1-50.5	50.1	0.9	48.2-51.9		
	2006	48.3	1.1	46.1-50.5	48.2	0.4	47.4-48.9	46.3	0.7	45.0-47.6		
	2016	45.9	1.1	43.7-48.1	46.4	0.4	45.6-47.1	47.0	0.6	45.9-48.2		
	SPHC			86>16			86>96>06>16			86=96>06=16		
13-15 yrs	1986	52.3	1.1	20.2-54.4	53.4	0.4	52.7-54.1	53.0	1.1	50.9-55.2		
	1996	49.6	1.2	47.2-51.9	52.5	0.4	51.6-53.4	53.3	1.1	51.2-55.4		
	2006	46.5	1.4	43.7-49.3	52.0	0.5	51.0-52.9	51.6	1.0	49.6-53.6		N=O>T
	2016	46.6	1.3	44.0-49.1	50.6	0.4	49.8-51.5	49.5	0.7	48.0-50.9		N>T
	SPHC			86>06			86>16					
CV Fitness - step test index												
				Thin (T)			Normal (N)			Owt/Ob (O)		
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC	
7-9 yrs	1986	53.2	0.9	51.4-54.9	51.7	0.4	50.8-52.6	46.3	1.3	43.7-49.0		T=N>O
	1996	53.1	1.9	49.3-56.8	49.5	0.5	48.5-50.6	47.8	1.4	45.0-50.5		
	2006	51.5	2.5	46.6-56.5	51.1	0.6	49.8-52.3	48.3	1.1	46.2-50.5		
	2016	49.9	1.2	47.5-52.4	51.5	0.5	50.5-52.5	49.3	0.8	47.7-50.8		
	SPHC						86>96					
10-12 yrs	1986	54.9	1.1	52.5-57.0	52.5	0.4	51.8-53.3	46.1	1.1	43.9-48.3		T=N>O
	1996	49.4	1.3	46.9-51.9	50.8	0.5	49.8-51.7	45.7	1.2	43.3-48.0		N>O
	2006	50.6	1.4	47.8-53.4	49.7	0.5	48.7-50.7	47.1	0.9	45.4-48.8		
	2016	52.3	1.5	49.4-52.4	51.7	0.5	50.7-52.7	47.7	0.8	46.2-49.2		T=N>O
	SPHC			86>96			86>06					
13-15 yrs	1986	52.4	1.3	49.8-55.1	50.8	0.5	49.9-51.7	45.5	1.4	42.8-48.3		T=N>O
	1996	52.6	1.5	49.6-55.5	52.0	0.6	50.9-53.2	46.9	1.4	44.3-49.6		T=N>O
	2006	51.6	1.8	48.0-55.1	50.2	0.6	49.0-51.4	48.0	1.3	45.5-50.5		
	2016	52.4	1.7	49.1-55.6	51.2	0.6	50.2-52.3	47.3	0.9	45.5-49.1		N>O
	SPHC											

[†]a lower time in the agility test indicates a better performance

Table 3. Age-adjusted means (M) and standard errors (SE) based on age-group specific ANCOVAs (age, age^2 as covariates) and significant post hoc comparisons (SPHC, $p<0.05$) between weight status groups within survey (right column) and between surveys within weight status group (horizontal) for each fitness test among GIRLS.

Speed – 5 m dash (m/s)

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	4.0	0.3	3.89-4.02	3.9	0.2	3.88-3.95	3.8	0.5	3.72-3.92	
	1996	3.9	0.5	3.77-3.95	3.8	0.2	3.80-3.88	3.7	0.5	3.60-3.80	
	2006	3.4	0.7	3.23-3.49	3.5	0.2	3.46-3.55	3.4	0.4	3.33-3.49	
	2016	3.5	0.4	3.42-3.56	3.5	0.2	3.51-3.59	3.4	0.2	3.38-3.47	N>O
	SPHC	86=96>06=16			86=96>06=16			86=96>06=16			
10-12 yrs	1986	4.3	0.3	4.23-4.34	4.2	0.1	4.22-4.27	4.1	0.4	4.00-4.23	T=N>O
	1996	4.1	0.4	4.07-4.22	4.1	0.2	4.10-4.17	3.9	0.4	3.81-3.96	
	2006	3.9	0.4	3.77-3.93	3.8	0.2	3.80-3.88	3.8	0.3	3.72-3.85	
	2016	3.9	0.4	3.86-4.01	3.9	0.2	3.85-3.92	3.7	0.3	3.66-3.77	T=N>O
	SPHC	86=96>06=16			86=96>06=16			86>06=16			
13-15 yrs	1986	4.4	0.4	4.37-4.52	4.5	0.2	4.43-4.50	4.3	0.4	4.18-4.34	N=T>O
	1996	4.3	0.4	4.18-4.33	4.2	0.2	4.20-4.27	4.1	0.6	3.97-4.18	T=N>O
	2006	4.1	0.5	3.98-4.17	4.0	0.2	4.00-4.08	3.9	0.4	3.84-4.00	
	2016	4.1	0.5	4.02-4.23	4.1	0.2	4.04-4.11	3.8	0.4	3.75-3.90	
	SPHC	86>96>06=16			86>96>06=16			86>06=16			

Agility – figure-of-eight run (s)†

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	18.7	0.2	18.3-19.1	19.0	0.1	18.8-19.2	19.2	0.3	18.6-19.8	
	1996	18.6	0.3	18.0-19.2	18.1	0.1	17.8-18.3	18.4	0.3	17.8-19.0	
	2006	16.9	0.4	18.1-19.8	18.1	0.1	17.9-18.4	18.6	0.3	18.1-19.2	
	2016	18.3	0.2	17.9-18.8	18.4	0.1	18.1-18.6	18.7	0.2	18.4-19.1	
	SPHC				96=06=16<86						
10-12 yrs	1986	17.4	0.2	17.0-17.7	17.1	0.1	16.9-17.2	17.7	0.2	17.3-18.2	N=T<O
	1996	16.4	0.2	16.0-16.8	16.5	0.1	16.3-16.7	17.1	0.2	16.6-17.5	
	2006	16.7	0.2	16.3-17.2	16.9	0.1	16.7-17.1	17.2	0.2	16.8-17.5	
	2016	17.0	0.2	16.5-17.4	17.0	0.1	16.8-17.2	17.8	0.2	17.4-18.1	T=N<O
	SPHC	86>96			86>96						
13-15 yrs	1986	16.6	0.2	16.2-17.0	16.8	0.1	16.6-17.0	17.0	0.2	16.6-17.4	
	1996	16.4	0.2	16.0-16.7	16.3	0.1	16.1-16.4	16.6	0.3	16.1-17.2	
	2006	16.0	0.2	15.5-16.5	16.2	0.1	16.0-16.4	16.9	0.2	16.5-17.3	N<O
	2016	16.3	0.3	15.8-16.8	16.2	0.1	16.0-16.4	17.3	0.2	16.9-17.7	N=T<O
	SPHC				86>96=06=16						

Explosive Power - vertical jump (cm)

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	19.9	0.5	18.9-20.9	19.6	0.3	19.0-20.1	18.2	0.8	16.6-19.7	
	1996	21.4	0.7	19.9-22.8	21.6	0.3	20.9-22.2	19.5	0.8	17.9-21.0	
	2006	18.2	1.1	16.1-20.2	21.6	0.4	20.9-22.3	21.5	0.7	20.2-22.8	N>T
	2016	20.7	0.6	19.5-21.8	21.8	0.3	21.2-22.4	19.2	0.4	18.4-19.9	N>O
	SPHC				86<96=06=16			86<06			

10-12 yrs	1986	25.3	0.5	24.3-26.3	25.9	0.3	25.4-26.4	22.7	0.7	21.3-24.2	N=T>O
	1996	28.2	0.7	26.9-29.6	27.7	0.3	27.0-28.3	23.6	0.7	22.3-25.0	T=N>O
	2006	28.2	0.7	26.8-29.7	26.1	0.3	25.4-26.7	24.4	0.6	23.2-25.6	T>O
	2016	26.9	0.7	25.5-28.4	27.3	0.3	26.6-27.9	23.9	0.5	22.8-24.9	N-T>O
	SPHC			86<96=06			86<96=16				
13-15 yrs	1986	32.5	0.8	30.9-34.0	32.2	0.3	31.6-32.8	28.6	0.8	27.0-30.2	T=N>O
	1996	31.9	0.8	30.4-33.4	31.8	0.4	31.1-32.5	28.5	1.1	26.3-30.7	N>O
	2006	33.4	1.0	31.4-35.4	32.3	0.4	31.5-33.0	29.3	0.8	27.7-31.0	T=N>O
	2016	32.9	1.1	30.8-34.9	32.6	0.4	31.9-33.4	27.7	0.8	26.1-29.3	T=N>O
	SPHC										

Flexibility – forward bend (cm)

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	51.0	0.7	49.6-52.4	52.4	0.4	51.7-53.1	55.4	1.1	53.2-57.5	O>N=T
	1996	47.9	1.0	45.9-49.9	50.2	0.5	49.3-51.0	51.1	1.1	49.0-53.3	
	2006	49.0	1.5	46.2-51.9	48.2	0.5	47.2-49.2	47.1	0.9	45.3-48.9	
	2016	47.6	0.8	46.0-49.2	50.5	0.4	49.7-51.4	49.7	0.5	48.7-50.8	N>T
	SPHC						86>96=16>06			86>96>06=16	
10-12 yrs	1986	51.4	0.7	50.1-52.7	53.3	0.3	52.6-53.9	54.0	0.9	52.2-55.8	
	1996	51.2	0.8	49.6-52.9	51.9	0.4	51.2-52.7	52.3	0.9	50.6-53.9	
	2006	51.2	0.9	49.3-53.0	50.3	0.4	49.5-51.1	49.7	0.8	48.2-51.2	
	2016	50.0	0.9	48.2-51.8	51.3	0.4	50.5-52.1	50.6	0.7	49.3-51.9	
	SPHC						86>=06=16			86>06=16	
13-15 yrs	1986	55.0	0.9	53.2-56.8	56.7	0.4	56.0-57.4	57.4	1.0	55.5-59.3	
	1996	52.0	0.9	50.3-53.8	54.9	0.4	54.1-55.7	58.0	1.3	54.4-60.5	O=N>T
	2006	52.6	1.2	50.3-54.9	54.6	0.5	53.7-55.5	55.5	1.0	53.6-57.4	
	2016	54.3	1.2	51.8-56.7	55.2	0.4	55.3-56.1	54.8	1.0	52.9-56.7	
	SPHC						86>96=06				

CV Fitness - step test index

		Thin (T)			Normal (N)			Owt/Ob (O)			
Age Group	Year	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	SPHC
7-9 yrs	1986	46.5	0.8	44.8-48.1	48.1	0.4	47.3-49.0	44.9	1.3	42.3-47.4	
	1996	47.9	1.2	45.5-50.2	46.3	0.5	45.3-47.4	45.8	1.3	43.3-48.3	
	2006	50.2	1.7	46.8-53.6	49.4	0.6	48.3-50.6	47.6	1.1	45.5-49.7	
	2016	51.1	1.0	49.2-53.0	48.6	0.5	47.6-49.5	45.4	0.6	44.2-46.7	T=N>O
	SPHC			86<16			96<06=16				
10-12 yrs	1986	45.7	0.7	44.3-47.2	45.2	0.4	44.5-45.9	43.0	1.1	40.9-45.0	
	1996	45.1	0.9	43.2-46.9	45.3	0.4	44.4-46.1	42.2	1.0	40.3-44.1	N>O
	2006	46.0	1.0	44.0-48.0	46.8	0.5	44.9-47.8	46.2	0.8	44.5-47.8	
	2016	44.6	1.0	42.5-46.6	46.3	0.5	45.4-47.2	45.1	0.7	43.7-46.6	
	SPHC									96<06	
13-15 yrs	1986	42.0	0.9	40.3-43.7	41.6	0.3	41.0-42.3	37.5	0.9	34.8-39.2	T=N>O
	1996	44.2	0.8	42.6-45.8	44.1	0.4	43.3-44.9	41.1	1.2	38.7-43.5	
	2006	44.4	1.1	42.3-46.5	44.8	0.4	44.0-45.7	43.1	0.9	41.3-44.9	
	2016	44.5	1.1	42.3-46.8	43.2	0.4	42.4-44.0	44.3	0.9	42.6-46.0	
	SPHC						86<96=06			86<06=16	

[†]a lower time in the agility test indicates a better performance

Table 4. Results of the regressions by year of each test (dependent variable) on the BMI (independent variable) with two models: linear (fitness = a + b * BMI) and nonlinear quadratic (fitness = a + b * BMI + c * BMI^2), where a, b and c are constants: BOYS

		Linear Model				Quadratic Model				
Age	Year	R^2	a	b	F	R^2	a	b	c	F
Speed - 5 m dash (m/sec)										
7-9	1986	0.00	4.15	-0.02		0.05	1.63	2.25**	-2.28**	**
	1996	0.00	4.03	-0.05		0.03	2.01	1.28*	-1.63*	*
	2006	0.02	3.85	-0.13		0.03	3.04	0.91	-1.05	
	2016	0.03	4.01	-0.18		0.04	3.41	0.39	-0.57	*
10-12	1986	0.02	4.69	-0.15**	**	0.06	2.45	1.93**	-2.00**	**
	1996	0.05	4.63	-0.22**	**	0.05	4.41	-0.02	-0.21	**
	2006	0.05	4.41	-0.23**	**	0.05	4.46	-0.27	0.05	**
	2016	0.04	4.37	-0.20**	**	0.05	3.63	0.55	-0.75	**
13-15	1986	0.00	4.70	0.01		0.07	1.76	2.53**	-2.54**	**
	1996	0.01	4.68	-0.11*	*	0.06	2.13	1.88**	-1.99**	**
	2006	0.00	4.40	-0.03		0.09	1.76	2.44**	-2.48**	**
	2016	0.02	4.66	-0.15**	**	0.04	3.34	1.15**	-1.30**	**
Agility - figure-of-eight run (sec)†										
7-9	1986	0.01	19.46	-0.08		0.04	33.67	-1.81**	1.74**	**
	1996	0.00	17.61	0.02		0.01	24.81	-0.99	1.02	
	2006	0.00	17.18	0.03		0.00	17.71	-0.07	0.10	
	2016	0.16	16.40	0.13*		0.03	23.13	-0.93*	1.07*	
10-12	1986	0.01	15.68	0.07		0.02	23.36	-1.27**	1.35**	**
	1996	0.03	14.60	0.17**	**	0.04	16.80	-0.36	0.54	**
	2006	0.06	13.92	0.24**	**	0.08	20.08	-1.03*	1.28**	**
	2016	0.05	14.07	0.21**	**	0.05	16.24	-0.25	0.47	**
13-15	1986	0.01	14.52	0.12	**	0.02	18.69	-0.72	0.85	**
	1996	0.01	14.36	0.12*	*	0.07	21.96	-2.11**	2.24**	**
	2006	0.07	12.67	0.26**	**	0.09	18.84	-1.15*	1.42**	**
	2016	0.03	13.44	0.18**	**	0.04	17.36	-0.82	0.99*	**
Explosive Power - vertical jump (cm)										
7-9	1986	0.00	21.76	-0.02		0.03	-9.97	1.63**	-1.67**	**
	1996	0.00	22.04	0.00		0.01	0.44	1.15	-1.15	
	2006	0.01	26.77	-0.11		0.03	5.40	1.19	-1.30	
	2016	0.01	24.29	-0.10		0.03	3.22	1.32**	-1.42**	*
10-12	1986	0.01	30.19	-0.09*	*	0.03	-3.99	1.45**	-1.55**	**
	1996	0.05	35.77	-0.23**	**	0.07	22.19	0.55	-0.78*	**
	2006	0.05	36.24	-0.23**	**	0.05	29.90	0.14	-0.38	**
	2016	0.09	37.60	-0.29**	**	0.09	40.06	-0.43	0.14	**
13-15	1986	0.00	34.85	0.01		0.08	-42.11	2.74**	-2.75**	**
	1996	0.00	38.93	-0.05		0.07	-19.07	2.31**	-2.38**	**
	2006	0.00	37.27	0.06		0.06	-14.67	2.02**	-1.97**	**
	2016	0.01	43.12	-0.11*	*	0.07	-5.97	1.91**	-2.03**	**
Flexibility - forward bend (cm)										
7-9	1986	0.05	48.31	0.07		0.09	35.20	0.69	-0.63	
	1996	0.00	47.30	0.04		0.00	42.99	0.23	-0.20	
	2006	0.03	42.38	0.16*		0.03	32.80	0.70	-0.54	
	2016	0.04	49.13	-0.07	*	0.01	63.18	-0.84	0.78*	

10-12	1986	0.03	44.51	0.16**	**	0.03	29.43	0.80	-0.65**	
	1996	0.00	47.89	0.05		0.01	36.10	0.64	-0.59	
	2006	0.00	50.21	-0.06		0.01	41.69	0.35	-0.41	
	2016	0.00	44.74	0.05		0.00	47.14	-0.08	0.13	
13-15	1986	0.00	49.93	0.06		0.02	21.86	1.15*	-1.10*	*
	1996	0.02	45.97	0.14*	*	0.04	13.09	1.54**	-1.41**	**
	2006	0.03	43.47	0.17**	**	0.10	-11.39	2.36**	2.20**	**
	2016	0.01	44.99	0.12*	*	0.04	9.61	1.57**	-1.46**	**
CV Fitness (step test index)										
7-9	1986	0.04	63.64	-0.19**	**	0.04	16.80	0.19	-0.38	**
	1996	0.02	57.37	-0.14		0.02	54.98	-0.06	-0.08	
	2006	0.29	57.79	-0.17*		0.03	61.89	-0.34	0.18	
	2016	0.01	55.34	-0.10	*	0.02	36.90	0.65	-0.75	*
10-12	1986	0.09	70.99	-0.31**	**	0.10	57.54	0.11	-0.42	**
	1996	0.04	59.18	-0.19**	**	0.04	47.16	0.26	-0.46	**
	2006	0.04	56.80	-0.19	**	0.04	54.39	-0.07	-0.11	**
	2016	0.05	62.00	-0.21**	**	0.05	53.12	0.11	-0.32	**
13-15	1986	0.05	64.51	-0.22**	**	0.05	48.59	0.25	-0.48	**
	1996	0.04	62.59	-0.19**	**	0.04	51.51	0.16	-0.35	**
	2006	0.03	58.22	-0.16**	**	0.03	46.25	0.29	-0.46	*
	2016	0.02	58.99	-0.15**	**	0.02	45.95	0.28	-0.42	**

†For the agility test, a lower time indicates better fitness.

*p<0.05, **p<0.01

Table 5. Results of the regressions by year of each test (dependent variable) on the BMI (independent variable) with two models: linear (fitness = a + b * BMI) and nonlinear quadratic (fitness = a + b * BMI + c * BMI^2), where a, b and c are constants: GIRLS

		Linear Model				**Quadratic Model**				
Age	Year	R^2	a	b	F	R^2	a	b	c	F
Speed - 5 m dash (m/sec)										
7-9	1986	0.02	4.20	-0.15**	**	0.03	0.09	-0.25	-0.25	**
	1996	0.02	4.15	-0.13*	*	0.02	3.55	0.32	-0.46	
	2006	0.00	3.6	-0.70		0.06	1.38	2.36**	2.44**	**
	2016	0.01	3.66	-0.12	*	0.16	3.50	0.05	-0.18	*
10-12	1986	0.02	4.46	-0.13**	**	0.04	3.04	1.44**	-1.57	
	1996	0.06	4.54	-0.24**	**	0.06	3.83	0.50	-0.75	**
	2006	0.00	3.85	-0.01		0.00	3.42	0.47	-0.49	
	2016	0.04	4.15	-0.19**	**	0.04	3.89	0.11	-0.30	**
13-15	1986	0.02	4.72	-0.15**	**	0.06	3.18	1.45**	-1.62	**
	1996	0.04	4.62	-0.20**	**	0.04	4.12	0.28	-0.49	**
	2006	0.03	4.28	-0.16**	**	0.03	4.39	-0.29	0.14	*
	2016	0.05	4.49	-0.23**	**	0.06	3.74	0.51	-0.75	**
Agility - figure-of-eight run (sec)†										
7-9	1986	0.00	18.54	-0.02		0.00	19.09	-0.04	-0.069	
	1996	0.00	17.85	0.03		0.01	24.05	-0.93	0.96	
	2006	0.00	17.39	0.07		0.01	23.31	-0.90	0.97	
	2016	0.00	18.08	0.05		0.00	18.33	0.00	0.05	

10-12	1986	0.00	16.63	0.08		0.01	21.74	-0.83	0.88*	
	1996	0.02	15.42	0.14**	**	0.03	18.89	-0.66	0.81	**
	2006	0.00	16.97	-0.01		0.00	18.47	-0.31	0.31	
	2016	0.01	16.08	0.12*	*	0.01	16.58	0.02	0.10	
13-15	1986	0.01	15.77	0.11*	*	0.03	21.26	-1.03*	1.14**	**
	1996	0.01	15.41	0.10		0.20	18.99	-0.68	0.79	*
	2006	0.02	14.99	0.15*	*	0.02	16.14	-0.10	0.25	*
	2016	0.03	14.80	0.17**	**	0.06	22.84	1.48**	1.67**	**
Explosive Power - vertical jump (cm)										
7-9	1986	-0.01	22.69	0.09		0.00	19.09	-0.04	-0.07	*
	1996	0.02	26.09	-0.14*	*	0.03	8.55	0.81	-0.96	*
	2006	0.00	21.20	0.01		0.00	21.39	0.00	0.01	
	2016	-0.02	23.93	-0.14**	**	0.02	23.28	-0.89	-0.05	*
10-12	1986	0.00	28.10	-0.07		0.03	0.55	1.44**	1.53**	**
	1996	0.04	34.03	-0.20**	**	0.05	16.03	0.80	-1.01*	
	2006	0.02	30.24	-0.14	**	0.02	33.84	-0.37	0.23	*
	2016	0.04	32.09	-0.19**	**	0.04	26.21	0.17	-0.37	**
13-15	1986	0.04	39.05	-0.19**	**	0.05	18.06	0.85*	-1.05*	**
	1996	0.02	36.41	-0.13**	*	0.05	5.82	1.38**	-1.52**	**
	2006	0.03	38.16	-0.17	**	0.04	23.89	0.56	-0.74	**
	2016	0.08	42.33	-0.28**	**	0.09	20.76	0.83	-1.11	**
Flexibility - forward bend (cm)										
7-9	1986	0.01	47.26	0.12*	*	0.02	37.92	0.54	-0.42*	
	1996	0.14	45.00	0.12		0.01	42.51	0.23	-0.11	
	2006	0.00	50.44	-0.06		0.01	66.21	-0.76	0.71	
	2016	0.00	48.95	0.03		0.00	43.36	0.34	-0.31	
10-12	1986	0.01	48.58	0.11**	**	0.01	40.50	0.49	-0.39	**
	1996	0.00	50.57	0.04		0.01	30.81	1.04*	-1.01*	**
	2006	0.00	49.96	0.01		0.00	50.09	0.00	0.01	
	2016	0.01	48.08	0.08		0.01	55.19	-0.28	0.39	
13-15	1986	0.02	50.19	0.15**	**	0.03	27.91	1.14**	-1.00*	**
	1996	0.06	44.63	0.25**	**	0.06	34.11	0.74	-0.50	**
	2006	0.03	47.69	0.17**	**	0.03	45.40	0.28	-0.12	*
	2016	0.01	50.58	0.09		0.10	43.27	0.38	-0.29	
CV Fitness (step test index)										
7-9	1986	0.00	50.23	-0.05		0.02	24.72	0.77*	-0.83**	*
	1996	0.01	52.18	-0.11		0.01	48.89	0.01	-0.12	
	2006	0.24	56.44	-0.16*	*	0.03	50.06	0.09	-0.26	
	2016	0.07	57.72	-0.27**	**	0.08	63.12	-0.06	0.28	**
10-12	1986	0.03	53.55	-0.17	**	0.03	39.87	0.36	-0.54	**
	1996	0.03	51.50	-0.16**	**	0.03	45.89	0.09	-0.25	**
	2006	0.00	46.56	0.00		0.00	37.77	0.39	-0.39	
	2016	0.01	49.36	-0.09		0.02	35.83	0.58	-0.37	*
13-15	1986	0.05	49.74	-0.23**	**	0.06	32.88	0.65	-0.89*	**
	1996	0.01	47.78	-0.09		0.01	36.29	0.42	-0.52	
	2006	0.00	45.70	-0.03		0.00	43.08	0.10	-0.14	
	2016	0.00	45.43	-0.05		0.00	39.58	0.22	-0.26	

†For the agility test, a lower time indicates better fitness.
*p<0.05, **p<0.001

In contrast, results for Polish youth in 2016 and Brazilian youth in 2013 (Lopes et al., 2019) were variable. Among Brazilian youth of both sexes, the relationship between the standing long jump and BMI was curvilinear among youth of both sexes 10-11 and 12-13, but was curvilinear among boys and linear among girls 14-15 years. Among Polish youth, the relationship between the vertical jump and BMI was linear at 10-12 years but curvilinear at 13-15 years in both sexes. For cardiovascular fitness, the relationship was linear between the BMI and multi-stage shuttle run in Brazilian girls 10-11, 12-13 and 14-15 years, but that between the BMI and step test in Polish was curvilinear among girls 10-12 years, but linear among girls 13-15 years.

The present study is not without limitations. An indicator of the biological maturity status of the youth was not available. Maturity status influences body size and also performances on tests of strength, speed and power. Individual differences in the timing of the growth spurts in height and weight are a potential confounder. The spurt occurs, on average, earlier in height than in weight in both sexes, and the respective spurts occur, on average, earlier in girls than in boys (Malina et al., 2004). The differential timing of the growth spurts can influence the BMI per se and also relationships between the BMI and tests of fitness during the transition into and through adolescence.

Conclusion

Relationships between the BMI and five tests of physical fitness were considered in rural Polish youth in four decennial surveys spanning 1986 through 2016. Performances on the tests differed significantly among weight status groups of boys and girls, with the exception of flexibility among boys 7-9 years and boys and girls 10-12 years. Although performances differed significantly among surveys except for cardiovascular fitness among boys 7-9 and 13-15 years and power among girls 13-15 years, the interactions between weight status and year of survey, however, did not consistently differ. Results of the sex-specific regressions of each fitness test on the BMI varied among age groups and across surveys due likely to the concentrations of youth within the normal weight range and proportionally fewer youth at both extremes of the BMI. The results, however, did suggest reasonably consistent curvilinear relationships between performances and the BMI in boys more so than in girls, but the explained variances were generally low. The hypothesis of a curvilinear association between the BMI and fitness test performances was thus partially supported.

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