AKADEMIA KULTURY FIZYCZNEJ
im. Bronisława Czecha w Krakowie

Szkoła Doktorska
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii

Rozprawa doktorska
Cykl publikacji naukowych

mgr Paulina Artymiak

Zmiany składu ciała oraz sprawności motorycznej dzieci (11-15 lat) z Krakowa podczas pandemii COVID-19

Promotor:
dr hab. Łukasz Kryst, prof. AKF
Promotor pomocniczy:
dr Magdalena Żegleń

Kraków, 2025

Serdeczne podziękowania
kieruję do moich przyjaciół oraz rodziny
za nieocenione wsparcie, cierpliwość oraz obecność
w trudnych chwilach podczas przygotowania niniejszej dysertacji.
Słowa wdzięczności składam również wszystkim, którzy swoją życzliwością
i chęcią pomocy motywowali mnie do ukończenia tej pracy.

Streszczenie

W marcu 2020 roku, kiedy nowy koronawirus SARS-CoV-2 rozprzestrzenił się na cały świat, wywołując zespół ostrej niewydolności oddechowej, Światowa Organizacja Zdrowia ogłosiła COVID-19 jako globalną pandemię. W odpowiedzi na dynamiczne zwiększenie liczby zachorowań, rządy na całym świecie wprowadziły restrykcje mające na celu zapobieganie dalszemu rozprzestrzenianiu się wirusa. Jako element tych działań zamknięto placówki szkolne, obiekty sportowe oraz wprowadzono ograniczenia w przemieszczaniu się, powodując pośrednio spadek poziomu aktywności fizycznej, wydłużenie czasu sedentaryjnego oraz czasu spędzonego przed ekranem. Wprowadzone ograniczenia spowodowały niekorzystne zmiany w składzie ciała oraz poziomie sprawności motorycznej, które są kluczowymi parametrami w ocenie obecnego i przyszłego stanu zdrowia oraz zapobieganiu chorobom przewlekłym, w szczególności wśród młodych ludzi. Celem dysertacji była ocena zmian składu ciała i sprawności motorycznej dzieci w wieku szkolnym, jakie nastąpiły w czasie pandemii SARS-CoV-2. Niniejsza rozprawa doktorska opiera się na analizie badań przekrojowych, przeprowadzonych wśród dzieci i młodzieży krakowskiej w latach 2020 i 2022 (przed i po pandemii COVID-19). Badania obejmowały losowo wybrane szkoły podstawowe, zlokalizowane w czterech głównych dzielnicach miasta Krakowa. Grupa badana obejmowała dzieci i młodzież w wieku 11-15 lat. Składała się łącznie z 590 uczestników w 2022 roku oraz 1045 uczestników w 2020 roku. W celu dokonania analizy porównawczej, badani zostali podzieleni ze względu na wiek i płeć, a dokładny wiek kalendarzowy każdego badanego obliczono jako różnicę między datą urodzenia, a datą badania, wyrażoną jako ułamek dziesiętny. Dokonano wybranych pomiarów antropometrycznych. Skład ciała był oceniany metodą bioimpedancji. Ponadto, sprawność motoryczna została oceniona za pomocą zmodyfikowanego testu EUROFIT. Wszystkie analizy statystyczne w celu porównania różnic między grupami zostały przeprowadzone w programie Statistica 13.3. Wyniki badań oraz szczegółowe ich interpretacje opublikowano w pięciu, powiązanych tematycznie artykułach naukowych, stanowiących kompletną analizę składu ciała oraz sprawności motorycznej badanej grupy. Analiza wykazała istotny statystycznie spadek poziomu sprawności motorycznej w większości testów sprawnościowych. Odnotowano również istotne statystycznie różnice w pomiarach grubości fałdów skórno-tłuszczowych oraz wyższe wartości we wskaźnikach otłuszczenia ciała wśród nastolatków. Odnotowano także wyższe wartości wskaźnika masy ciała (BMI) oraz częstości występowania nadwagi i otyłości, które były zależne od płci. Z kolei analiza wyników masy

mięśniowej oraz procentowej zawartości tkanki tłuszczowej, nie wykazała znaczących różnic w okresie przed i po pandemii COVID-19. Dodatkowo, zaobserwowano zwiększenie wartości obwodu bioder ze statystycznie istotną różnicą w zależności od płci. Z drugiej strony, nie wszystkie wyniki badań wskazywały na pogorszenie parametrów składu ciała. W badaniu zaobserwowano istotne zwiększenie siły chwytu prawej oraz lewej ręki, a także spadek wartości obwodu talii w większości grup wiekowych. Wyniki przeprowadzonych badań wskazują, iż ograniczenia wprowadzone przez rząd w celu zapobiegania rozprzestrzenianiu się wirusa SARS-CoV-2 miały negatywny wpływ na skład ciała oraz poziom sprawności motorycznej wśród dzieci i młodzieży krakowskiej. Niekorzystne zmiany w obrębie analizowanych parametrów oraz wyników testów motorycznych mogą być związane z ograniczeniem aktywności fizycznej, wydłużonym czasem sedentaryjnym oraz czasem spędzonym przed ekranem. Poprawa niektórych wyników może być spowodowana aktywnością fizyczną w domu lub na podwórku, czy też tą podejmowaną w miarę łagodzenia restrykcji podczas pandemii COVID-19. Potrzebne są dalsze badania w celu oceny, czy ograniczenia wprowadzone podczas pandemii koronawirusa będą miały długoterminowy negatywny wpływ na skład ciała oraz sprawność motoryczną dzieci i młodzieży.

Abstract

In March 2020, when the new coronavirus SARS-CoV-2 spread across all over the world, causing acute respiratory distress syndrome, the World Health Organization declared COVID-19 a global pandemic. In response to the dynamic increase in the number of cases, governments around the world introduced restrictions aimed at preventing the further spread of the virus. As part of these actions, schools, as well as sports facilities were closed, and movement restrictions were introduced, indirectly causing, a decrease in physical activity levels, an increase of sedentary time, and screen time. The restrictions introduced caused unfavorable changes in body composition and motor fitness levels, which are key parameters in assessing the current and future health status and in preventing chronic diseases, particularly among young people. The aim of dissertation was to assess changes in body composition and physical fitness of school-aged children that occurred during the SARS-CoV-2 pandemic. This doctoral dissertation is based on the analysis of cross-sectional studies conducted among children and adolescents from Kraków in the years 2020 and 2022 (before and after the COVID-19 pandemic). The studies included randomly selected primary schools located in four main districts of the city of Kraków. The study group included children and adolescents aged 11–15 years. Consisted of a total of 590 participants in 2022 and 1,045 participants in 2020. For comparative analysis, the participants were divided according to age and sex, and the exact calendar age of each participant was calculated as the difference between the date of birth and the date of the examination, expressed as a decimal fraction. Selected anthropometric measurements were taken. Body composition was assessed using the bioelectrical impedance method. In addition, motor fitness was assessed using a modified EUROFIT test. All statistical analyses to compare differences between groups were conducted using the Statistica 13.3 software. The results of the research and their detailed interpretations were published in five thematically related scientific articles, constituting a complete analysis of body composition and motor fitness of the studied group. The analysis showed a statistically significant decrease in motor fitness levels in most fitness tests. Statistically significant differences were also noted in the measurements of skinfold thickness and higher values of body fat indicators among adolescents. Higher values of body mass index (BMI) and prevalence of overweight and obesity were also recorded, which were dependent on sex. On the other hand, the analysis of muscle mass results and body fat percentage did not show significant differences in the period before and after the COVID-19 pandemic. Additionally, an increase in hip circumference values was observed,

with a statistically significant difference depending on sex. On the other hand, not all research results showed a deterioration in body composition parameters. The study observed a significant increase in handgrip strength of both the right and left hand, as well as a decrease in waist circumference values in most age groups. The results of the conducted research indicate that the restrictions introduced by the government to prevent the spread of the SARS-CoV-2 virus had a negative impact on body composition and the motor fitness levels among children and adolescents from Kraków. Adverse changes in the analyzed parametrers and motor tests may be related to reduced physical activity, prolonged sedentary time, and increased screen time. The improvement of some results may be due to physical activity at home or in the yard, or undertaken as restrictions were eased during the COVID-19 pandemic. Further research is needed to assess whether the restrictions introduced during the coronavirus pandemic will have a long-term negative impact on body composition and motor fitness in children and adolescents.

Struktura rozprawy doktorskiej pt.:

Zmiany składu ciała oraz sprawności motorycznej dzieci (11-15 lat) z Krakowa podczas pandemii COVID-19

przygotowanej jako cykl tematycznie powiązanych publikacji naukowych, obejmującej pięć artykułów opublikowanych:

1. Artymiak P, Żegleń M, Kryst Ł. (2024). Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic. J Phys Act Health. 2024 Mar 13;21(5):500-507. doi: 10.1123/jpah.2023-0577;
2. Artymiak P, Żegleń M, Kryst Ł. (2024). Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic. Anthropol Anz. 2025 Feb 11;82(1):1-6. doi: 10.1127/anthranz/2024/1746;
3. Artymiak P, Żegleń M, Kryst Ł. (2024). The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland). Pediatr Obes. 2024 Oct;19(10):e13160. doi: 10.1111/ijpo.13160;
4. Artymiak P, Żegleń M, Kryst Ł. (2025). The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population. Am J Hum Biol. 2025 Jan;37(1):e24182. doi: 10.1002/ajhb.24182;
5. Artymiak P, Żegleń M, Kryst Ł. (2025). Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11-15 from Kraków during the COVID-19 pandemic. Anthropol. Rev. *87*(4), 55–67. https://doi.org/10.18778/1898-6773.87.4.04.

Spis treści

1. Uzasadnienie wyboru tematu badań

W grudniu 2019 roku w mieście Wuhan, położonym w chińskiej prowincji Hubei, zidentyfikowano nowy koronawirus (SARS-CoV-2), należący do grupy betakoronawirusów. Wirus ten w krótkim czasie rozprzestrzenił się na całym świecie, prowadząc do wybuchu pandemii COVID-19, którą Światowa Organizacja Zdrowia (WHO) oficjalnie ogłosiła w marcu 2020 roku i obowiązywała do 5 maja 2023 r. (Kwok et al., 2020, Ryan i in., 2020, Salfi i in., 2020, UN, 2023). Choroba wywołana przez SARS-CoV-2 charakteryzuje się szerokim spektrum manifestacji klinicznych, obejmujących przypadki od bezobjawowych, po ciężkie powikłania takie jak zapalenie płuc oraz zespół ostrej niewydolności oddechowej (Ryan i in, 2020, Kwok i in., 2020). Rosnąca liczba zakażeń stanowiła poważne wyzwanie dla systemów opieki zdrowotnej oraz zdrowia publicznego na wszystkich kontynentach (Pranata i in., 2021).

W odpowiedzi na gwałtowny wzrost liczby zakażeń rządy na całym świecie wdrożyły szereg środków zapobiegających, mających na celu ograniczenie transmisji wirusa. Restrykcje obejmowały zamknięcie placówek szkolnych, ograniczenie przemieszczania się, zamknięcie obiektów sportowych i rekreacyjnych oraz wprowadzenie pracy i nauczania w trybie zdalnym (Abbas, Kamel, 2020, Montemayor i in., 2022). W Polsce, podobnie jak w wielu innych krajach podjęto surowe środki zapobiegawcze, w tym zamknięcie basenów, siłowni, parków oraz placów zabaw. Ponadto wprowadzono zalecenia dotyczące zachowania dystansu społecznego, ograniczenia kontaktów interpersonalnych oraz pozostawania w domach (Ministerstwo Zdrowia, 2021).

Pomimo, że wprowadzone restrykcje były konieczne dla ograniczenia transmisji wirusa, miały one istotny wpływ na styl życia, poziom aktywności fizycznej oraz dietę społeczeństwa na całym świecie (Lesser i Nienhuis, 2020; Martinez-Ferran i in., 2020, Tison i in., 2020, Karatzi i in., 2021).

Istotne konsekwencje restrykcji rządowych spowodowanych pandemią COVID-19, zaobserwowano szczególnie wśród dzieci i młodzieży. W początkowej fazie pandemii młodzież była zmuszona do pozostania w domach, uczestnicząc w zajęciach w trybie zdalnym oraz utrzymując kontakty społeczne głównie za pośrednictwem technologii cyfrowych. Prowadziło to do wydłużenia czasu spędzonego w pozycji siedzącej oraz ekspozycji na ekrany urządzeń elektronicznych. Dodatkowo ograniczenie dostępu do zorganizowanych

form aktywności fizycznej oraz interakcji społecznych sprzyjających ruchowi mogło przyczynić się do zmniejszenia poziomu aktywności fizycznej w opisanej grupie (Moursi i in., 2023). Globalne badania obejmujące 1047 uczestników wykazały istotny spadek intensywnej i umiarkowanej aktywności fizycznej, a także redukcję czasu przeznaczanego na aktywność fizyczną podczas pandemii w porównaniu z okresem ją poprzedzającym. Ponadto, w tej samej grupie czas sedentaryjny wydłużył się o ponad 28%, a 27% ankietowanych zadeklarowało wydłużenie czasu biernego o co najmniej pięć godzin dziennie (Ammar i in., 2020). Przegląd systematyczny oraz metaanaliza obejmująca populacje z 14 krajów wykazały wyraźne obniżenie poziomu aktywności fizycznej wśród osób w wieku od 4 do 93 lat, niezależnie od płci (Wunsch i in., 2022). Wskazywano również na możliwość utrwalenia się wzorców niskiej aktywności fizycznej po zakończeniu pandemii SARS-CoV-2, co może mieć długofalowe konsekwencje zdrowotne (Chen i in., 2020). Zjawisko to budzi szczególne obawy wśród rodziców i opiekunów dzieci oraz młodzieży, u których procesy rozwojowe oraz nawyki zdrowotne znajdują się w fazie intensywnego kształtowania (Dunton i in., 2020). Sugeruje się, że młodzi ludzie, którzy doznali pandemii COVID-19, mogą mieć trudności w kształtowaniu zdrowych wzorców żywieniowych oraz utrzymaniu prawidłowego poziomu aktywności fizycznej (Yun, Lee, 2023).

Wnioskuje się, że siedzący tryb życia oraz niski poziom aktywności fizycznej w połączeniu z niekontrolowanym spożyciem pokarmu, negatywnie wpływa na sprawność motoryczną, szczególnie wśród dzieci i młodzieży (Kumar i in., 2015, Das i in., 2017, Jurak i in., 2021, Beghin i in., 2022, Zhou i in., 2022). Pomimo, iż pandemia koronawirusa negatywnie wpłynęła na styl życia ludzi na całym świecie, a w szczególności na sprawność motoryczną, jej konsekwencje w odmiennych warunkach społeczno-kulturowych nie zostały w pełni zbadane. Wstępne badania prowadzone na całym świecie wskazują na pogorszenie sprawności motorycznej wśród dzieci i młodzieży (Sunda i in., 2021; Wahl-Aleksander i Camic, 2021; Kidokoro i in., 2022). Podobne tendencje zaobserwowano również w Polsce, gdyż w okresie pandemii COVID-19 odnotowano spadek poziomu sprawności motorycznej wśród młodych osób (Artymiak i in., 2024). Wysoka sprawność układu mięśniowo-szkieletowego u dzieci i młodzieży sprzyja ogólnej poprawie stanu zdrowia, a także wiąże się ze zmniejszonym ryzykiem rozwoju chorób przewlekłych oraz zmiejsza ryzyko kardiometaboliczne (Silva i in., 2023).

Oprócz spadku sprawności motorycznej, obserwuje się również rozpowszechnienie niezdrowych wzorców żywieniowych, obejmujących spożywanie przetworzonej, czy gotowej

żywności, a także utrata kontroli nad ilością oraz kalorycznością przyjmowanych pokarmów wśród dzieci i młodzieży w czasie pandemii COVID-19 (Ammar i in., 2020).

Negatywne konsekwencje niezdrowego stylu życia, w tym ograniczony dostęp do aktywności fizycznej oraz zajęć pozaszkolnych wynikający z restrykcji wprowadzonych podczas pandemii COVID-19, przyczyniły się do zwiększenia się masy ciała oraz częstości występowania otyłości wśród dzieci i młodzieży (Loza i in., 2023; Kovacs i in., 2022; Androutsos i in., 2021; Woo i in., 2022). Przegląd systematyczny oraz metaanaliza wykazały wzrost wartości wskaźnika BMI, a także rozpowszechnienia nadwagi i otyłości u młodych osób w trakcie pandemii koronawirusa (Chang i in., 2021). Ponadto, wydłużony czas sedentaryjny oraz czas spędzony przed ekranem, będący efektem nudy wśród młodej populacji, sprzyjał nadmiernemu spożyciu żywności o wysokiej wartości energetycznej. W rezultacie doszło do zaburzenia równowagi energetycznej, polegającej na nadmiernej podaży kalorii w stosunku do jej wydatkowania. Przyczyniło się to do zwiększonego gromadzenia się tkanki tłuszczowej w organizmie (Karatzi i in., 2021). Zgodnie z danymi *Centers for Disease Control and Prevention,* osoby z otyłością należą do grupy o zwiększonym ryzyku ciężkiego przebiegu COVID-19 (CDC, 2020). Wykazano, że nadmierna masa ciała oraz związane z nią choroby przewlekłe, takie jak cukrzyca, nieleczone nadciśnienie czy astma, korelują ze zwiększonym ryzykiem powikłań związanych z SARS-CoV-2 (WOF, 2020).

Biorąc powyższe pod uwagę, niezwykle istotna jest ocena zmian składu ciała (tj. udziału mięśni i tkanki tłuszczowej), a także wzorca aktywności fizycznej u dzieci i młodzieży, zwłaszcza iż podobne badanie nie zostało dotychczas przeprowadzone w populacji polskiej. Wyniki takich badań mogą być szczególnie istotne, ponieważ, jak już sugerowano w populacjach z innych krajów, ograniczenia związane z COVID-19 mogą prowadzić do niekorzystnych zmian w składzie tkankowym ciała dzieci i młodzieży (Dunton i in., 2020; Fairclough i Stratton, 2006; Ridgers i in., 2012; Workman, 2020). Niniejsza dysertacja doktorska bazuje na przekrojowych badaniach populacyjnych, przeprowadzonych wśród dzieci i młodzieży szkolnej z Krakowa w latach 2020 i 2022 (przed i po pandemii COVID-19). Na potrzeby niniejszej rozprawy doktorskiej za okres trwania pandemii koronawirusa przyjmuje się przedział od 20 marca 2020 r. – w dniu ogłoszenia światowej epidemii wirusa SARS-CoV-2 przez WHO, do lutego 2022 r. kiedy zniesiono większość obostrzeń, w tym powrót uczniów do nauki stacjonarnej.

2. Cel pracy

Głównym celem niniejszej dysertacji była ocena zmian składu ciała i sprawności motorycznej dzieci w wieku szkolnym na przykładzie badanej grupy z Krakowa, jakie nastąpiły w czasie pandemii SARS-CoV-2.

2.1 Pytania badawcze

W cyklu artykułów naukowych wyszczególniono następujące problemy szczegółowe, na które udzielono odpowiedzi dzięki realizacji Indywidualnego Planu Badawczego:

1. Czy po pandemii zmieniła się sprawność motoryczna dzieci i młodzieży z Krakowa?
2. Czy po pandemii zmienił się wskaźnik BMI dzieci i młodzieży z Krakowa?
3. Czy po pandemii zmieniła się zawartość tkanki tłuszczowej w organizmie dzieci i młodzieży z Krakowa?
4. Czy po pandemii zmieniła się dystrybucja tkanki tłuszczowej u dzieci i młodzieży z Krakowa?
5. Czy po pandemii zmieniła się masa mięśniowa u dzieci i młodzieży z Krakowa?

2.2 Hipotezy badawcze

1. Uczestnicy badani po pandemii mają niższy poziom sprawności motorycznej w porównaniu z dziećmi badanymi przed pandemią.
2. Uczestnicy badani po pandemii mają wyższe wartości WHR (stosunek obwodu talii do obwodu bioder), WHtR (stosunek obwodu talii do wysokości ciała)i BMI w porównaniu z dziećmi badanymi przed pandemią.
3. Uczestnicy badani po pandemii mają większy obwód talii, bioder i kończyn w porównaniu z dziećmi badanymi przed pandemią.
4. Wśród uczestników badanych po pandemii występuje wyższy odsetek nadwagi i otyłości w porównaniu z dziećmi badanymi przed pandemią.
5. Uczestnicy badani po pandemii charakteryzują się mniej korzystną dystrybucją tkanki tłuszczowej w porównaniu z dziećmi badanymi przed pandemią.
6. Uczestnicy badani po pandemii mają większą grubość fałdu skórno-tłuszczowego nad tricepsem, pod dolnym kątem łopatki, na brzuchu, nad talerzem biodrowym i na podudziu w porównaniu z dziećmi badanymi przed pandemią.

7. Uczestnicy badani po pandemii mają niższą masę mięśniową w porównaniu z dziećmi badanymi przed pandemią.
8. Uczestnicy badani po pandemii mają wyższą procentową zawartość tkanki tłuszczowej w organizmie w porównaniu z dziećmi badanymi przed pandemią.

3. Harmonogram realizacji

Cykl publikacji naukowych			
Autor	Rok	Tytuł	Odpowiedźna pytanie badawcze
Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst	2024	Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic	1
Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst	2024	Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic	2, 3
Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst	2024	The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland)	4
Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst	2025	The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population	3, 4
Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst	2025	Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11-15 from Kraków during the COVID-19 pandemic.	3, 5

4. Struktura rozprawy doktorskiej

Rozprawa doktorska składa się z pięciu publikacji naukowych, które są ze sobą powiązane tematycznie. Zostały one opublikowane w czasopismach spełniających wymogi Ustawy o szkolnictwie wyższym i nauce (Dz. U. z 2020 r. poz. 85 ze zm.) i wpisane do wykazu czasopism naukowych i materiałów recenzowanych z konferencji międzynarodowych zwanego dalej „Wykazem MNiSW". Seria publikacji naukowych niniejszej rozprawy obejmuje następujące artykuły:

1. Artymiak P, Żegleń M, Kryst Ł. (2024). Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic (Zał. 1);
    - Artykuł został opublikowany w czasopiśmie Journal of Physical Activity and Health

    Impact Factor: 2,9 , Punktacja MNiSW: 70

    artykuł zawiera: 4 tabele, 30 pozycji piśmiennictwa; wkład autorski: Artymiak, P. = 60%, Żegleń, M. = 20% Kryst, Ł. 20% (Zał. 6);
2. Artymiak P, Żegleń M, Kryst Ł. (2024). Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic (Zał. 2);
    - Artykuł został opublikowany w czasopiśmie Antropologischer Anzeiger

    Impact Factor: 0,4 , Punktacja MNiSW: 70

    artykuł zawiera: 4 tabele, 25 pozycji piśmiennictwa; wkład autorski: Artymiak, P. = 60%, Żegleń, M. = 20% Kryst, Ł. 20% (Zał. 7);
3. Artymiak P, Żegleń M, Kryst Ł. (2024). The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland) (Zał. 3);
    - Artykuł został opublikowany w czasopiśmie Pediatric Obesity

    Impact Factor: 3,910 , Punktacja MNiSW: 100

    artykuł zawiera: 6 tabel, 32 pozycje piśmiennictwa; wkład autorski: Artymiak, P. = 60%, Żegleń, M. = 20% Kryst, Ł. 20% (Zał. 8);

4. Artymiak P, Żegleń M, Kryst Ł. (2025). The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population (Zał. 4);
    - Artykuł został opublikowany w czasopiśmie American Journal of Human Biology

    Impact Factor: 1,6 , Punktacja MNiSW: 70

    artykuł zawiera: 4 tabele, 34 pozycji piśmiennictwa; wkład autorski: Artymiak, P. = 60%, Żegleń, M. = 20% Kryst, Ł. 20% (Zał. 9);
5. Artymiak P, Żegleń M, Kryst Ł. (2025). Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11-15 from Kraków during the COVID-19 pandemic (Zał. 5);
    - Artykuł został opublikowany w czasopiśmie Anthropological Review

    Impact Factor: -, Punktacja MNiSW: 70

    artykuł zawiera: 2 tabele, 2 ryciny, 45 pozycji piśmiennictwa; wkład autorski: Artymiak, P. = 60%, Żegleń, M. = 40% Kryst, Ł. 40% (Zał. 10);

Łączna punktacja cyklu publikacji: Impact Factor: 8,81 ; punktacja MNiSW: 380

5. Materiały i metody

Niniejsza rozprawa doktorska bazuje na badaniach przekrojowych, przeprowadzonych wśród dzieci i młodzieży z Krakowa w latach 2020 i 2022. Badaniem objęto losowo wybrane szkoły podstawowe zlokalizowane w czterech głównych dzielnicach miasta: Śródmieście, Nowa Huta, Podgórze i Krowodrza. Dane antropometryczne dla kohorty badanej w 2022 roku zostały zgromadzone w okresie wiosennym, od marca do czerwca, a następnie poddane analizie porównawczej z danymi pochodzącymi z projektu „Dziecko Krakowskie 2020". W ramach tego projektu pomiary przeprowadzono w okresie zimowo-wiosennym, od stycznia do marca 2020 roku, bezpośrednio przed pandemią COVID-19. W obu badaniach uwzględniono te same placówki edukacyjne, co umożliwiło analizę zmian w kontekście pandemii.

Wszystkie procedury zastosowane w ramach niniejszej dysertacji były zgodne z normami etycznymi odpowiednich krajowych i instytucjonalnych komisji ds. eksperymentów na ludziach oraz z Deklaracją Helsińską z 1975 r., zrewidowaną w 2008 r. i zostały zatwierdzone przez Komisję Bioetyczną Regionalnego Stowarzyszenia Medycznego (5/KBL/OIL/2019, 66/KBL/OIL/2022). Na potrzeby badania otrzymano zgody dyrektorów szkół, rodziców lub opiekunów prawnych oraz samych badanych. Wykonano pomiary antropometryczne uczestników badania oraz metodą bioimpedancji oceniono skład ciała, a następnie za pomocą zmodyfikowanego Europejskiego testu sprawności fizycznej –EUROFIT 1993, przeprowadzono testy sprawności motorycznej.

Kryteriami włączenia do badania była zgoda rodzica lub opiekuna prawnego oraz samego badanego oraz brak przeciwwskazań do wysiłku fizycznego.

5.1 Charakterystyka grup badawczych

W ramach badań wchodzących w skład rozprawy doktorskiej przebadano łącznie 593 uczestników (w tym 288 dziewcząt i 305 chłopców) w 2022 roku oraz 1070 uczestników (558 dziewcząt i 512 chłopców) w ramach projektu „Dziecko Krakowskie 2020" (Tabela 1). Liczebność próby różni się nieznacznie w poszczególnych publikacjach, ze względu na brak kompletnych danych dla wszystkich uczestników.

Tabela 1. Liczebność badanych grup.

Kategoria wieku [lata]	2020		2022	
	Dziewczęta	Chłopcy	Dziewczęta	Chłopcy
11	171	115	94	72
12	107	110	78	79
13	87	115	54	77
14	93	79	44	46
15	100	93	18	31
Razem	558	512	288	305
	1070		593	
	1663			

Badane dzieci były w wieku od 11 do 15 lat. Grupa badana została podzielona ze względu na wiek oraz płeć, a dokładny wiek kalendarzowy każdego badanego obliczono jako różnicę między datą urodzenia, a datą badania, wyrażoną jako ułamek dziesiętny. Na tej podstawie badani zostali zaklasyfikowani do jednej z pięciu grup wiekowych, od 10,50 do 15,49 (przykład: w grupie 14-latków znajdą się dzieci w wieku kalendarzowym od 13,50 do 14,49).

5.2 Metody zastosowane w pracach badawczych

W badaniu zastosowano standardowe metody oceny parametrów antropometrycznych oraz sprawności motorycznej. Pomiary antropometryczne przeprowadzono zgodnie z techniką Martina (Martin i Saller, 1957), natomiast grubość fałdów skórno-tłuszczowych oceniono metodą Tannera (Tanner, 1962). Pomiary antropometryczne, które wymagały określenia strony ciała, wykonano po prawej stronie. Masę ciała, określono za pomocą wagi elektronicznej (Tanita, UM-076, Japonia, z dokładnością 0.1 kg). Natomiast procentową zawartość tkanki tłuszczowej uzyskano za pomocą segmentowego analizatora składu ciała (Tanita, model BC-418, Japonia, dokładność 0,1%); skład ciała oceniono metodą bioimpedancji (BIA). Podczas badania dzieci były ubrane w strój sportowy, natomiast podczas pomiaru wysokości ciała oraz analizy BIA dzieci były boso. Pomiary antropometryczne oraz testy sprawności motorycznej zostały przeprowadzone w godzinach porannych.

Na podstawie pomiarów wysokości ciała oraz masy ciała, obliczono wskaźnik masy ciała (BMI) według wzoru:

$$\frac{masa\ ciała(kg)}{wysokość\ ciała^2(m^2)}.$$

Pomiary antropometryczne obejmowały:

- wysokość ciała – mierzona od powierzchni, na której stoi badany, do punktu vertex, z głową badanego ustawioną w płaszczyźnie frankfurckiej, za pomocą antropometru (GPM, Zurych, Szwajcaria), z dokładnością do 1 mm;
- obwód talii – mierzony w największym przewężeniu tułowia w talii, w bezdechu, za pomocą taśmy antropometrycznej z dokładnością do 5 mm;
- obwód bioder – mierzony przez najbardziej wysunięte ku tyłowi punkty pośladków, za pomocą taśmy antropometrycznej z dokładnością do 5 mm;
- obwód podudzia - mierzony w miejscu największego rozwoju mięśni łydki, przy rozluźnionej kończynie, za pomocą taśmy antropometrycznej z dokładnością do 5 mm;
- obwód ramienia – mierzony w miejscu największego rozwoju mięśnia dwugłowego ramienia, kończyna opuszczona swobodnie w dół, a mięśnie rozluźnione, za pomocą taśmy antropometrycznej z dokładnością do 5 mm.

Na postawie pomiarów wysokości ciała oraz wybranych obwodów ciała, obliczono wskaźniki WHR (stosunek obwodu talii do obwodu bioder) i WHtR (stosunek obwodu talii do wysokości ciała) według następujących wzorów:

- **WHR**

$$\frac{obwód\ talii\ (cm)}{obwód\ bioder\ (cm)}$$

- **WHtR**

$$\frac{obwód\ talii\ (cm)}{wysokość\ ciała\ (cm)}$$

Pomiary grubości fałdów skórno-tłuszczowych zostały zmierzone automatycznym fałdomierzem zegarowym GPM (Szwajcaria) o stałym nacisku 10g/mm^2 i dokładności 0,5 mm. Pomiary obejmowały:

- fałd skórno-tłuszczowy nad tricepsem - fałd podłużny mierzony w pozycji stojącej, przy rozluźnionej kończynie, w połowie długości ramienia nad mięśniem trójgłowym;
- fałd skórno-tłuszczowy pod dolnym kątem łopatki – fałd skośny mierzony w pozycji stojącej, w dół i w bok od dolnego kąta łopatki;
- fałd skórno-tłuszczowy na brzuchu - fałd poprzeczny mierzony w pozycji stojącej, ok. 5 cm w bok oraz poniżej około 1 cm od linii pępka;
- fałd skórno-tłuszczowy nad talerzem biodrowym – fałd skośny mierzony w pozycji stojącej, nad górnym brzegiem grzebienia biodrowego;
- fałd skórno-tłuszczowy na podudziu - fałd podłużny mierzony w pozycji strojącej przy odciążonej kończynie, bocznie od dołu podkolanowego.

Na podstawie zmierzonych grubości fałdów skórno-tłuszczowych obliczono wskaźniki otłuszczenia:

- **Wskaźnik otłuszczenia tułowia:**

$$\left[\frac{(pod\ dolnym\ kątem\ łopatki\ +na\ \ brzuchu\ +\ nad\ talerzem\ biodrowym)}{(nad\ tricepsem\ +\ pod\ dolnym\ kątem\ łopatki\ +\ nad\ talerzem\ biodrowym\ +\ na\ brzuchu\ +\ na\ podudziu)}\right] *\ 100$$

- **Stosunek otłuszczenia kończyn do całkowitej sumy grubości fałdów skórno-tłuszczowych:**

$$\left[\frac{(nad\ tricepsem\ +\ na\ podudziu)}{(nad\ tricepsem\ +\ pod\ dolnym\ kątem\ łopatki\ +\ nad\ talerzem\ biodrowym\ +\ na\ brzuchu\ +\ na\ podudziu)}\right] *\ 100$$

- **Otłuszczenie kończyn do otłuszczenia tułowia:**

$$\left[\frac{(nad\ tricepsem\ +\ na\ podudziu)}{(pod\ dolnym\ kątem\ łopatki\ +\ na\ brzuchu)}\right] *\ 100$$

- **Suma fałdów skórno-tłuszczowych:**

$$[nad\ tricepsem\ +\ na\ brzuchu\ +\ pod\ dolnym\ kątem\ łopatki\ +\ nad\ talerzem\ biodrowym\ +\ na\ podudziu]$$

Sprawność motoryczna została oceniona za pomocą zmodyfikowanego Europejskiego testu sprawności fizycznej– EUROFIT 1993–dostosowanego do metod badań porównawczych realizowanych w ramach projektu „Dziecko Krakowskie 2020". Przeprowadzone testy obejmowały:

- siłę eksplozywną mięśni kończyn dolnych – skok w dal z miejsca z pozycji stojącej wykonywany dwa razy, każdy mierzony taśmą mierniczą (dokładność 1 cm) do pięty stopy badanego;do analizy wybierano dłuższy ze skoków;
- siła statyczna – maksymalna siła ręki mierzona dynamometrem (Baseline, Stany Zjednoczone, z dokładnością 1 kg) z regulowanym uchwytem, odpowiednim do zastosowania w populacji pediatrycznej; pomiar był wykonywany dwa razy dla każdej ręki, oba zostały zapisane i najlepszy (obserwacja dla silniejszej ręki) został wzięty pod uwagę podczas analizy wyników;
- siła mięśniowa górnej części ciała – rzut piłką lekarską o masie 2 kg, wykonany 2 razy oburącz znad głowy; odległość była mierzona nieelastyczną taśmą z dokładnością do 1 cm; brany pod uwagę podczas analizy wyników był dłuższy rzut;
- szybkość i zwinność – bieg wahadłowy (10 razy 5 metrów); badani na sygnał badacza pobiegli jak najszybciej do drugiej linii położonej 5 m dalej i pięć razy powrócili na linię startu; czas był mierzony stoperem z dokładnością do 0,01 s;
- test gibkości – badani stojąc na specjalnie przygotowanym podeście wykonali z pozycji stojącej maksymalny skłon do przodu, który oceniany był z dokładnością do 1 cm za pomocą nieelastycznej taśmy przymocowanej do platformy; badani wykonali test dwa razy, oba zostały zarejestrowane, a lepszy został wykorzystany podczas analizy;
- siady z leżenia– badani będący w siadzie ugiętym na materacu z założonymi rękami skrzyżnie na klatce piersiowej, wykonali jak największą ilość siadów z leżenia dotykając każdorazowo plecami materaca oraz klatką piersiową kolan w czasie 1 minuty, czas mierzony stoperem z dokładnością do 0,01s.

Dodatkowo, wybrane wyniki testów sprawnościowych zostały znormalizowane, co umożliwiło porównanie wyników badanych o różnej wielkości ciała. Znormalizowano wyniki:

- **siły chwytu prawej i lewej ręki**

$$znormalizowana\ siła\ chwytu\ = \frac{siła\ chwytu}{masa\ ciała}$$

- **skok w dal z miejsca**

$$znormalizowany\ skok\ w\ dal\ z\ miejsca\ = \frac{skok\ w\ dal\ z\ miejsca}{wysokość\ ciała}$$

Ponadto, w celu obliczenia skorygowanej powierzchni mięśni ramienia (CAMA), dokonano pomiaru obwodu ramienia za pomocą nieelastycznej taśmy antropometrycznej oraz pomiaru grubości fałdu skórno-tłuszczowego na tricepsie przy użyciu fałdomierza zegarowego. Na podstawie zgromadzonych danych dla każdego badanego obliczono za pomocą CAMA, całkowitą masę mięśniową [kg], stosując równanie predykcyjne:

Wzór dla kobiet:

$$CAMA = [(MAC - (\pi\ x\ TSF))2/4\pi] - 6{,}5$$

Wzór dla mężczyzn:

$$CAMA = [(MAC - (\pi\ x\ TSF))2/4\pi] - 10$$

gdzie: TSF – fałd skórno-tłuszczowy nad tricepsem [mm], MAC - obwód środkowej części ramienia [cm].

$$Masa\ mięśniowa\ (kg) = H\ x\ (0{,}0264 + (0{,}0029\ x\ CAMA))$$

gdzie: H – wysokość ciała [cm].

Szczegółowy opis pozostałych metod badawczych zastosowanych w poszczególnych artykułach, wchodzących w skład niniejszej dysertacji został przedstawiony w rozdziale nr 6 pt.„Wyniki”.

5.3 Metody analizy statystycznej

Na potrzeby niniejszej dysertacji doktorskiej przeprowadzono analizy statystyczne za pomocą arkusza kalkulacyjnego w programie Microsoft Excel oraz oprogramowania Statistica 13.3. Każda z analizowanych cech została przedstawiona w postaci średniej ($\overline{x}$) oraz odchylenia standardowego (SD). Do oceny normalności rozkładu zastosowano test Shapiro-Wilka, a wybór odpowiedniego testu statystycznego oparto na wynikach tego testu. Analiza statystyczna obejmowała porównanie różnic między grupami z 2022 oraz 2020 roku. W zależności od spełnienia założeń normalności rozkładu zastosowano dwukierunkową analizę wariancji ANOVA oraz test post hoc Tukey'a. Natomiast w przypadku niespełnienia założeń o normalności rozkładu ocenianej testem Shapiro-Wilka, zastosowano nieparametryczny test Kruskala-Wallisa. W przypadku wykrycia istotnego statystycznie efektu głównego czynnika ($p< 0,05$, $p< 0,01$ lub $p< 0,001$) w teście ANOVA, przeprowadzono analizę post hoc Tukey'a.

Dodatkowo, do oceny istotnych statystycznie różnic w częstości występowania niedowagi, prawidłowej masy ciała, nadwagi i otyłości dla kategorii wiekowych i płci zastosowano test Chi^2.

Dla czytelności niniejszej rozprawy doktorskiej w rozdziale „wyniki" przedstawiono skrócone wersje zestawień tabelarycznych. Szczegółowe dane tabelaryczne zamieszczono w załącznikach.

6. Wyniki

Niniejszy rozdział zawiera analizę wyników przeprowadzonych badań i systematycznie odpowiada na hipotezy badawcze postawione w rozdziale 2.2.

Jednym z kluczowych elementów oceny zdrowia i rozwoju dzieci i młodzieży jest sprawność motoryczna. W artykule pt.: Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic (załącznik 1) wchodzącym w skład niniejszej dystertacji dokonano analizy zmian sprawności motorycznej młodzieży w wieku 11-15 lat z Krakowa podczas pandemii COVID-19. W badaniu przekrojowym wzięło udział łącznie 1635 osób (załącznik 1, tabela1). Sprawność motoryczna została oceniona za pomocą zmodyfikowanego testu EUROFIT 1993, którego metodologia została szczegółowo opisana w sekcji "5.2. Metody zastosowane w pracach badawczych".

Analiza wykazała istotne statystycznie zwiększenie czasu biegu wahadłowego we wszystkich grupach wiekowych, u obu płci (tabela 2). Wśród dziewcząt i chłopców zaobserwowano spadek ilości wykonanych siadów z leżenia, przy czym różnice istotne statystycznie odnotowano u dziewcząt w wieku 11 oraz 13 lat, a także u chłopców 11-14 letnich (tabela 2). Wśród obu płci zaobserwowano spadek wartości skoku w dal z miejsca – u chłopców był n istotny statystycznie w wieku 11 oraz 14 lat (tabela3). Analizy nie wskazały na istnienie istotnych różnic w znormalizowanym skoku w dal z miejsca w badanej grupie (załącznik 1, tabela 6). Odnotowano również różnice w zakresie wyników testu gibkości oraz w rzucie piłką lekarską znad głowy wśród dziewcząt. Jednak nie wszystkie wyniki testów sprawności motorycznej uległy pogorszeniu (tabela 2). U dziewcząt oraz chłopców odnotowano wzrost siły chwytu prawej i lewej ręki w większości grup wiekowych. Istotny statystycznie wzrost siły chwytu prawej ręki stwierdzono u dziewcząt w wieku 11-12 lat oraz u chłopców 12 i 14-letnich. W przypadku siły chwytu lewej ręki istotne różnice odnotowano u dziewcząt w wieku 11-12 lat, a także wśród 11 i 15 letnich chłopców (tabela 3). Ponadto, zaobserwowano istony statystycznie wzrost znormalizowanej siły chwytu w większości grup wiekowych u obu płci (załącznik 1, tabela 6).

Tabela 2. Wartości średnie analizowanych parametrówi ich różnice pomiędzy badaniami z 2020 i 2022 roku w obrębie kategorii wiekowej – wersja skrócona tabeli 4 z załącznika 1.

Kategoria wieku [lata]	Test gibkości			Rzut piłką lekarską znad głowy			Bieg wahadłowy			Siady z leżenia		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\bar{x}$	$\bar{x}$		$\bar{x}$	$\bar{x}$		$\bar{x}$	$\bar{x}$		$\bar{x}$	$\bar{x}$	
Dziewczęta												
11	49,41	50,01	0,60	408,05	400,09	-7,96	21,81	23,83	2,02 ***	22,20	20,39	-1,82 ***
12	49,82	48,88	-0,94	485,61	463,38	-22,23	21,45	23,25	1,80 ***	22,55	21,29	-1,26
13	50,78	53,72	2,93	516,24	541,27	25,03	20,12	22,40	2,28 ***	24,13	22,40	-1,73 *
14	52,23	51,97	-0,26	590,69	529,58	-61,12	20,23	23,28	3,05 ***	22,70	23,05	0,35
15	53,51	52,69	-0,81	592,64	670,69	78,04	20,76	23,09	2,33 ***	22,59	24,53	1,94
Chłopcy												
11	43,09	47,56	4,47 ***	473,56	523,18	49,62*	20,50	22,54	2,04 ***	23,28	21,48	-1,8 *
12	45,03	44,39	-0,64	534,07	541,11	7,04	19,80	22,23	2,43 ***	24,49	21,93	-2,56 ***
13	43,72	46,04	2,32	632,86	602,31	-30,55	19,47	22,63	3,16 ***	25,65	23,13	-2,52 ***
14	42,93	46,19	3,26	787,23	699,94	-87,30	18,57	22,57	4,00 ***	25,91	23,79	-2,12 *
15	47,13	48,39	1,26	809,60	866,55	56,95	18,17	20,92	2,74 ***	26,84	27,78	0,94

*- $p<0,05$, **- $p<0,01$, ***- $p<0,001$

Tabela 3. Wartości średnie analizowanych parametrów i ich różnice pomiędzy badaniami z 2020 i 2022 roku w obrębie kategorii wiekowej – wersja skrócona tabeli 5 z załącznika 1.

Kategoria wieku [lata]	Skok w dal z miejsca			Siła chwytu prawej ręki			Siła chwytu lewej ręki		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\bar{x}$	$\bar{x}$		$\bar{x}$	$\bar{x}$		$\bar{x}$	$\bar{x}$	
Dziewczęta									
11	137,71	137,40	-0,31	15,47	16,60	1,13*	14,15	15,33	1,18*
12	142,58	142,07	-0,51	18,57	20,66	2,09*	16,89	18,84	1,96**
13	153,00	151,66	-1,34	21,33	22,04	0,71	19,22	21,00	1,78
14	149,83	152,98	3,15	22,46	23,68	1,22	20,96	21,98	1,02
15	154,46	164,56	10,10	25,32	26,06	0,74	23,45	24,44	0,99
Chłopcy									
11	144,25	147,60	3,35	16,60	18,39	1,79**	15,23	17,76	2,53**
12	155,92	152,51	-3,41	19,83	20,52	0,69*	18,42	18,30	-0,12
13	161,77	163,50	1,73	22,36	24,47	2,11	21,23	21,96	0,73
14	178,97	177,02	-1,95	26,77	27,96	1,19***	24,75	25,85	1,09
15	195,24	201,16	5,92	30,90	37,45	6,55	29,26	35,60	6,34***

*- $p<0,05$, **- $p<0,01$, ***- $p<0,001$

Analiza wyników prowadzi do wniosku, iż restrykcje wprowadzone przez rząd w celu ograniczenia rozprzestrzeniania się wirusa SARS-CoV-2 miała istotny niekorzystny wpływ na poziom sprawności motorycznej krakowskiej młodzieży, jednak nie wszystkie wyniki uległy pogorszeniu. Co najważniejsze, wyniki badań wskazują, iż restrykcje takie jak nauka zdalna, ograniczenia w przemieszczaniu się, czy zamknięcie obiektów sportowych przyczyniły się do pogorszenia parametrów wytrzymałościowych i siłowo-szybkościowych, szczególnie w biegu wahadłowym, skoku w dal oraz liczbie wykonanych siadów z leżenia. Dodatkowo, zaobserwowano wzrost siły chwytu. Rozbieżności w analizowanych wynikach mogą wynikać ze zmian nawyków aktywności fizycznej związanych z wiekiem, które mogą mieć wpływ na rozwój siły mięśni.

Kolejnym aspektem realizacji Indywidualnego Planu Badawczego była ocena zmian wskaźnika BMI oraz częstości występowania nadwagi i otyłości u dzieci i młodzieży (11-15 lat) z Krakowa w okresie pandemii COVID-19, którą opisano w artykule pt.: Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic (załącznik 2).

W celu porównania różnic pomiędzy grupami obliczono wskaźnik BMI, a dla każdej kategorii wiekowej obliczono średnią i odchylenie standardowe dla pomiarów wysokości ciała, masy ciała oraz samego BMI. Następnie zgodnie z punktami odcięcia Cole'a

(Australian Health Survey, 2011–2013) badanych pogrupowano jako osoby z niedowagą, prawidłową masą ciała lub nadwagą/otyłością. Zastosowanie powyższych punktów odcięcia umożliwiło jednolitą i standaryzowaną klasyfikację na podstawie BMI, umożliwiając porównanie wyników z 2022 r. z wynikami z 2020 r.

Analiza wyników wykazała zwiększenie częstości występowania niedowagi oraz prawidłowej masy ciała w większości grup wiekowych u obupłci, przy czym różnicę istotną statystycznie odnotowano jedynie dla częstości występowania niedowagi wśród 14-letnich dziewcząt. Jednocześnie, u chłopców zaobserwowano wzrost częstości występowania nadwagi w wieku 11, 12 i 15 lat. Wśród dziewcząt, we wszystkich kategoriach wiekowych zaobserwowano zmniejszenie częstości występowania nadwagi, przy czym różnice istotne statystycznie odnotowano w grupie 14-latek. Ponadto, zaobserwowano spadek odsetka badanej młodzieży z otyłością w większości kategorii wiekowych obu płci (tabela 4).

Tabela 4. Liczba [procent] dziewcząt oraz chłopców w kategorii BMI w latach 2022 i 2020 oraz ich różnice – połączenie tabeli 4 i 5 z załącznika 2.

Kategoria wieku [lata]	Kohorta	Niedowaga n [%]	Zmiana w czasie [%]	Prawidłowa masa ciała n [%]	Zmiana w czasie [%]	Nadwaga n [%]	Zmiana w czasie [%]	Otyłość n [%]	Zmiana w czasie [%]
Dziewczęta									
11	2020	16 [9,41]	1,22	130 [76,47]	1,18	20 [11,76]	-0,06	4 [2,35]	-1,29
	2022	10 [10,63]		73 [77,65]		11 [11,70]		1[1,06]	
12	2020	7 [6,54]	8,84	79 [73,83]	-7,17	21 [19,62]	-2,96	1[0,93]	0,35
	2022	12 [15,38]		52 [66,66]		13 [16,66]		1 [1,28]	
13	2020	7 [8,04]	1,21	70 [80,45]	2,88	6 [6,88]	-1,34	4 [4,59]	-2,74
	2022	5 [9,25]		45 [83,33]		3 [5,55]		1 [1,85]	
14	2020	6 [6,45]	11,73*	65 [69,89]	5,11	19 [20,43]	-15,89*	3 [3,22]	-0,95
	2022	8 [18,18]		33 [75,00]		2 [4,54]		1 [2,27]	
15	2020	10 [10,00]	-4,45	70 [70,00]	18,88	14 [14,00]	-8,45	6 [6,00]	-0,45
	2022	1 [5,55]		16 [88,88]		1 [5,55]		1[5,55]	
Suma	2020	46[8,24]	4,17	414 [74,19]	1,32	80 [14,33]	-3,99	18 [3,22]	-1,50
	2022	36 [12,41]		219 [75,51]		30 [10,34]		5 [1,72]	
Chłopcy									
11	2020	9 [7,82]	1,90	80 [69,56]	-5,68	21 [18,26]	1,18	5 [4,34]	2,60
	2022	7 [9,72]		46 [63,88]		14 [19,44]		5 [6,94]	
12	2020	8 [7,27]	-0,94	75 [69,09]	3,06	20 [18,18]	2,07	6 [5,45]	-4,19
	2022	5 [6,33]		57 [72,15]		16 [20,25]		1 [1,26]	
13	2020	9 [7,82]	-1,33	74 [64,34]	9,86	29 [25,22]	-10,94	3 [2,60]	2,59
	2022	5 [6,49]		57 [74,02]		11 [14,28]		4 [5,19]	
14	2020	3[3,79]	4,90	57 [72,15]	1,76	17 [21,51]	-6,30	2 [2,53]	-0,43
	2022	4 [8,69]		34 [73,91]		7 [15,21]		1 [2,17]	
15	2020	6 [6,45]	0,00	67 [72,04]	-1,08	15 [16,12]	3,23	5 [5,37]	-2,15
	2022	2 [6,45]		22 [70,96]		6 [19,35]		1 [3,22]	
Suma	2020	35 [6,85]	0,69	353 [69,08]	1,74	102 [19,96]	-2,26	21 [4,10]	-0,17
	2022	23 [7,54]		216 [70,82]		54 [17,70]		12 [3,93]	

*p<0,05

Przeprowadzona analiza wykazała zatem, iż lockdown spowodowany pandemią koronawirusa wpłynął na wartości BMI oraz częstość występowania niedowagi, prawidłowej masy ciała, nadwagi/otyłości wśród badanej młodzieży, zmiany te różniły się w zależności od płci. Zaobserwowane zmiany mogły wynikać z ograniczeń aktywności fizycznej, wydłużonym czasem spędzanym w pozycji siedzącej oraz czaems spędzonym przed ekranem.

Kolejnym aspektem analizowanym na potrzeby niniejszej dysertacji była ocena zmian w rozmieszczeniu tkanki tłuszczowej i grubości fałdów skórno-tłuszczowych wśród nastolatków w wieku 11-15 lat z Krakowa w trakcie pandemii COVID-19 (załącznik 3), którą przedstawiono w artykule pt.: The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland). W badaniach przekrojowych przeprowadzonych w latach 2022 i 2020 wzięło udział łącznie 1662 badanych (załącznik 3, tabela 1).

Analiza wyników wykazała zwiększoną grubość fałdu skórno-tłuszczowego nad tricepsem oraz na podudziu wśród dziewcząt we wszystkich kategoriach wiekowych. Różnicę istotną statystycznie odnotowano u 11 i 12-latek. Ponadto, dziewczęta charakteryzują się wyższymi wartościami grubości fałdów skórno-tłuszczowych na brzuchu, pod dolnym kątem łopatki, nad talerzem biodrowym. Odnotowano też wyższe wartości sumy fałdów skórno-tłuszczowych w większości kategorii wiekowych. Istotną statystycznie różnicę zaobserwowano wśród 11-latek analizując, fałd skórno-tłuszczowy pod dolnym kątem łopatki, nad talerzem biodrowym oraz sumę fałdów (tabela 5). Analogicznie, wśród chłopców odnotowano wyższe wartości fałdów skórno-tłuszczowych na brzuchu, na podudziu, nad tricepsem, pod dolnym kątem łopatki oraz wyższe wartości sumy fałdów. Ponadto, chłopcy charakteryzowali się wyższymi wartościami grubości fałdu skórno-tłuszczowego nad talerzem biodrowym we wszystkich kategoriach wiekowych (tabela 6).

Tabela 5. Wartości średnie ($\overline{x}$) grubości fałdów skórno-tłuszczowych w poszczególnych kategoriach wiekowych i różnice między kohortami– skrócona wersja tabeli 4 z załącznika 3.

Kategoria wieku [lata]	Fałd nad tricepsem [mm]			Fałd pod dolnym kątem łopatki [mm]			Fałd na brzuchu [mm]		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$	
Dziewczęta									
11	8,97	10,01	1,04***	10,30	11,70	1,40***	12,30	13,09	0,79
12	9,08	10,02	0,94**	10,79	12,20	1,41	12,26	13,17	0,91
13	8,98	9,85	0,87	10,94	11,98	1,04	11,95	12,31	0,36
14	9,76	9,77	0,01	11,76	11,58	-0,18	12,83	12,59	-0,24
15	10,36	10,39	0,03	12,50	10,94	-1,56	12,27	13,36	1,09
Chłopcy									
11	10,06	10,75	0,69	10,94	12,94	2,00	14,27	15,80	1,53
12	9,64	10,25	0,61	11,42	11,92	0,50	14,15	13,59	-0,56
13	9,55	8,87	-0,68	11,57	11,33	-0,24	14,99	13,88	-1,11
14	8,08	8,97	0,89	9,88	11,49	1,61	12,65	12,91	0,26
15	7,53	8,39	0,86	10,16	11,11	0,95	11,65	12,34	0,69

** p<0,01;*** p<0,001

Tabela 6. Wartości średnie ($\overline{x}$) grubości fałdów skórno-tłuszczowych w poszczególnych kategoriach wiekowych i różnice między kohortami – skrócona wersja tabeli 5 z załącznika 3.

Kategoria wieku [lata]	Fałd nad talerzem biodrowym			Fałd na podudziu			Suma fałdów [mm]		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$	
Dziewczęta									
11	11,53	12,70	1,17*	8,81	11,46	2,65	52,01	58,96	6,95**
12	12,18	13,26	1,08	8,64	9,23	0,59	52,95	57,88	4,90
13	12,25	12,31	0,06	8,79	8,80	0,01	52,91	55,25	2,34
14	13,28	12,11	-1,17	9,01	9,04	0,03	56,65	55,10	-1,55
15	13,32	12,92	-0,40	9,33	9,44	0,11	57,77	57,05	-0,72
Chłopcy									
11	13,01	14,48	1,47	9,69	10,06	0,37	57,97	64,03	6,06
12	13,24	13,97	0,73	9,21	9,30	0,09	57,66	59,04	1,38
13	13,67	13,86	0,19	9,51	9,01	-0,50	59,30	56,95	-2,35
14	12,11	13,52	1,41	8,99	9,00	0,01	51,71	55,89	4,18
15	11,90	12,65	0,75	9,26	8,34	-0,92	50,50	52,82	2,32

* p<0,05;**p<0,01

Dodatkowo dziewczęta charakteryzowały się niższym poziomem otłuszczenia tułowia oraz otłuszczenia kończyn w stosunku do całkowitej zawartości tkanki tłuszczowej w organizmie. Odwrotną tendencję, zaobserwowano we wskaźniku otłuszczenia kończyn w stosunku do otłuszczenia tułowia, gdyż wartości były wyższe. Chłopcy, charakteryzowali się więc wyższym poziomem otłuszczenia tułowia w stosunku do całkowitej zawartości

tkanki tłuszczowej w organizmie. Natomiast, odwrotną tendencję odnotowano we wskaźnikach otłuszczenia kończyn do całkowitej zawartości tkanki tłuszczowej oraz otłuszczenia kończyn do tułowia (załącznik 3, tabela 6). Wyniki badań wskazują, iż pandemia COVID-19 negatywnie wpłynęła na zdrowie dzieci i młodzieży z Krakowa. Analiza badań wykazała wzrost grubości fałdów skórno-tłuszczowych oraz rozkładu tkanki tłuszczowej wśród populacji krakowskiej.

Pomimo braku kompleksowych badań dotyczących optymalnych metod określania nadmiernej masy ciała, powszechnie stosowane techniki oceny stanu odżywienia i rozmieszczenia tkanki tłuszczowej obejmują pomiar wysokości ciała, masy ciała oraz obwodów talii i bioder. Dodatkowo, wskaźniki takie jak WHR, WHtR dostarczają bardziej szczegółowych informacji na temat rozmieszczenia tkanki tłuszczowej w porównaniu do BMI. W niniejszym artykule pt.:The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population (załącznik 4), dokonano oceny zmian obwodu talii i bioder oraz wskaźników WHR i WHtR u młodzieży w wieku 11-15 lat z Krakowa w okresie pandemii COVID-19. W badaniach przekrojowych wzięło udział łącznie 1662 badanych (załącznik 4 tabela 1).

Wykonano pomiary wysokości ciała, obwodu talii oraz bioder. Dodatkowo, obliczono średnią oraz odchylenie standardowe pomiarów wysokości ciała, dla wszystkich kategorii wiekowych. Na podstawie uzyskanych wyników obwodów, obliczono wskaźniki WHR i WHtR. Szczegółowy opis pomiaru obwodów ciała oraz wzorów wskaźników WHR i WHtR przedstawiono w sekcji „5.2 Materiały zastosowane w pracach badawczych”.

Analiza statystyczna wykazała wzrost obwodu bioder w większości kategorii wiekowych u obu płci. Różnicę istotną statystycznie odnotowano wśród 13-letnich dziewcząt. W przypadku obwodu talii, wśród dziewcząt zaobserwowano niższe wartości w większości grup wiekowych. Istotną statystycznie różnicę odnotowano w wieku 11-12 i 14 lat (tabela 7). Odwrotną tendencję zaobserwowano wśród 14-15-letnich chłopców, z istotną statystycznie różnicą w wieku 15 lat.

Tabela 7. Wartości średnie ($\overline{x}$) analizowanych parametrów oraz ich różnice pomiędzy badaniami z 2020 i 2022 roku w obrębie kategorii wiekowych – skrócona wersja tabeli 3 z załącznika 4.

Kategoria wieku [lata]	Obwód talii [cm]			Obwód bioder [cm]		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$	
Dziewczęta						
11	62,83	59,95	-2,88***	76,31	77,30	0,99
12	64,76	62,78	-1,98*	81,08	82,64	1,56
13	66,19	65,42	-0,77	84,32	86,03	1,71*
14	68,61	64,94	-3,67***	88,38	86,99	-1,39
15	68,53	69,14	0,61	91,32	90,28	-1,04
Chłopcy						
11	66,58	65,10	-1,48	77,83	78,74	0,91
12	67,68	66,04	-1,64	81,61	80,83	-0,78
13	71,43	71,08	-0,35	85,28	85,42	0,14
14	71,11	73,72	2,61	87,89	89,17	1,28
15	74,70	77,03	2,33*	91,58	89,95	-1,63

* $p<0,05$;*** $p<0,001$

Ponadto, odnotowano niższe wartości WHR u obu płci w większości kategorii wiekowych. Różnicę istotną statystycznie odnotowano wśród 11-14 letnich dziewcząt oraz 11-12-letnich chłopców. Dodatkowo, u dziewcząt zaobserwowano niższe wartości WHtR, ze statystyczną istotną różnicą w wieku 11-12 i 14 lat. U chłopców w większości grup wiekowych, odnotowano obniżenie wartości wskaźnika WHtR, z jednoczesnym wzrostem wartości wśród 14 i 15 latków. Różnicę istotną statystycznie odnotowano u 11 i 15 latków (tabela 8).

Tabela 8. Wartości średnie ($\overline{x}$) analizowanych parametrów oraz ich różnice pomiędzy badaniami z 2020 i 2022 roku w obrębie kategorii wiekowej – skrócona wersja tabeli 4 z załącznika 4

Kategoria Wieku [lata]	WHR			WHtR		
	2020	2022	2022 vs 2020	2020	2022	2022 vs 2020
	$\overline{x}$	$\overline{x}$		$\overline{x}$	$\overline{x}$	
Dziewczęta						
11	0,82	0,78	-0,04***	0,43	0,41	-0,02***
12	0,80	0,76	-0,04***	0,42	0,40	-0,02***
13	0,79	0,76	-0,03***	0,42	0,41	-0,01
14	0,78	0,75	-0,03***	0,43	0,40	-0,03**
15	0,75	0,77	0,02	0,42	0,42	0,00
Chłopcy						
11	0,85	0,83	-0,02***	0,45	0,44	-0,01**
12	0,83	0,82	-0,01**	0,44	0,43	-0,01
13	0,84	0,83	-0,01	0,45	0,44	-0,01
14	0,81	0,83	0,02	0,42	0,44	0,02
15	0,81	0,82	0,01	0,43	0,44	0,01*

* $p<0,05$;** $p<0,01$;*** $p<0,001$

Podsumowując, w badanych kohortach ograniczenia związane z pandemią COVID-19 wpłynęły na obwód talii, bioder oraz wskaźniki WHR i WHtR wśród populacji z Krakowa.

W kolejnym artykule, wchodzącym w skład rozprawy doktorskiej zatytułowanym Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11-15 from Kraków during the COVID-19 pandemic, oceniono zmiany w składzie ciała, ze szczególnym uwzględnieniem masy mięśnioweji tkanki tłuszczowej, wśród nastolatków w wieku 11–15 lat z Krakowa w trakcie pandemii COVID-19 (załącznik 5). Próba badawcza obejmowała 1069 osób w 2020 roku oraz 593 osoby w 2022 roku (załącznik 5, tabela 1). Dane zebrane w 2022 roku porównano z wynikami z 2020 roku.

W ramach niniejszego badania zmierzono wysokość ciała oraz dokonano analizy procentowej zawartości tkanki tłuszczowej. Dodatkowo, dla każdego badanego za pomocą równania predykcyjnego, obliczono całkowitą masę mięśniową (kg). Dokładny opis metody badawczej znajduje się w sekcji „5.2 Metody zastosowane w pracach badawczych”.

Analiza wyników wykazała redukcję masy mięśniowej wśród dziewcząt w większości grup wiekowych. Różnicę istotną statystycznie zaobserwowano u 14-letnich dziewcząt. Odwrotną tendencję obserwuje się wśród chłopców, ponieważ w większości kategorii wiekowych odnotowano wzrost masy mięśniowej. Wśród dziewcząt, analiza procentowej zawartośći tkanki tłuszczowej wykazała spadek we wszystkich grupach wiekowych, różnica

istotna statystycznie występowała u 14 latek. U chłopców zaobserwowano wzrost procentowej zawartości tkanki tłuszczowej wśród 11, 13 i 15-latków (tabela 9).

Tabela 9. Średnia ($\overline{x}$) i odchylenie standardowe (SD) masy mięśniowej (kg) oraz procentowej zawartości tkanki tłuszczowej w poszczególnych kategoriach wiekowych i różnice między kohortami – tabela 2 z załącznika 5.

Kategoria wieku [lata]	Masa mięśniowa					Procentowa zawartość tkanki tłuszczowej				
	2020		2022		2022 vs 2020	2020		2022		2022 vs 2020
	$\overline{x}$	SD	$\overline{x}$	SD		$\overline{x}$	SD	$\overline{x}$	SD	
Dziewczęta										
11	14,50	3,76	14,72	3,67	0,22	19,96	6,35	19,45	6,26	-0,51
12	16,82	3,78	17,02	4,82	0,20	21,40	6,60	20,91	6,69	-0,49
13	18,11	3,83	17,62	3,51	-0,49	21,79	5,96	21,45	5,94	-0,34
14	21,03	4,40	18,55	4,75	-2,48**	24,11	6,53	21,00	6,52	-3,11**
15	21,60	4,57	20,49	3,83	-1,11	24,27	7,44	23,19	6,07	-1,08
Chłopcy										
11	14,97	3,68	15,93	4,87	0,96	16,88	6,63	18,07	7,03	1,19
12	17,91	5,05	17,37	4,74	-0,54	16,48	6,91	16,36	5,85	-0,12
13	20,09	4,66	19,84	5,28	-0,25	14,90	7,03	14,94	6,49	0,04
14	22,68	6,20	23,74	5,94	1,06	13,27	6,07	12,75	5,07	-0,52
15	27,11	6,57	27,50	6,47	0,39	13,01	6,75	14,24	5,46	1,23

**- $p<0,01$

Analiza wyników, wykazała również wzrost średniej masy mięśniowej w większości kategoriach wiekowych, w zależności od kategorii BMI wśród obu płci (załącznik 5,wykres 2). Dodatkowo we wszystkich kategoriach BMI zaobserwowano wzrost procentowej tkanki tłuszczowej zarówno u dziewcząt, jak i chłopców (załącznik 5, wykres 1). Zróżniocowane wyniki mogą być spowodowane zmianami w aktywności fizycznej, wydłużonym czasem sedenteryjnym, czy w czasie łagodzenia restrykcji spędzonym na świeżym powietrzu.

7. Podsumowanie i wnioski

Wprowadzone przez rządy restrykcje związane z pandemią COVID-19, które miały dążyć do zahamowania rozprzestrzeniania się wirusa SARS-CoV-2, negatywnie wpłynęły na zdrowie oraz styl życia ludzi na całym świecie. W związku z tym, ważne stało się pozyskanie aktualnych danych dotyczących wpływu pandemii koronawirusa na stan zdrowia dzieci i młodzieży. Wyniki wskazują na niekorzystne zmiany w większości parametrów antropometrycznych oraz poziomie sprawności motorycznej badanej populacji, które mogą być powiązane z ograniczeniem aktywności fizycznej, zwiększeniem czasu spędzanego w pozycji siedzącej oraz czasu spędzonego przed ekranem. Z drugiej strony, nie wszystkie wyniki uległy pogorszeniu. Zaobserwowane zmiany mogą być wynikiem dostosowania się do aktywności fizycznej w warunkach domowych lub na świeżym powietrzu w trakcie łagodzenia obostrzeń, a także naturalnymi zmianami zachodzącymi w okresie dojrzewania. W szerszym kontekście, wyniki badań mają praktyczne zastosowanie i powinny stanowić podstawę do tworzenia programów profilaktycznych i interwencyjnych, ukierunkowanych na poprawę kondycji fizycznej młodych ludzi, które pomogą powtrzymać skutki zmniejszonej aktywności fizycznej w okresie pandemii COVID-19. Dodatkowo, warto monitorować, czy wprowadzone ograniczenia związane z pandemią wirusa SARS-CoV-2 będą miały długoterminowy negatywny wpływ na parametry antropometryczne oraz sprawność motoryczną wśród dzieci i młodzieży. Analizując powyższe wyniki, należy zwrócić uwagę na pewne ograniczenia. Po pierwsze, przedłużony okres izolacji z powodu pandemii COVID-19 mógł być przyczyną zmiejszonej liczebności uczestników wśród młodzieży z najstarszej grupy wiekowej. Z drugiej strony, niniejsze badanie dostarcza cennych informacji na temat zmian składu ciała oraz sprawności motorycznej dzieci i młodzieży, które zaszły w okresie pandemii COVID-19. Dodatkowo, analiza badań przekrojowych pozwala

na porównanie, jak pandemia koronawirusa wpłynęła na zdrowie fizyczne dzieci i młodzieży z Krakowa.

Odpowiadając na pytania badawcze zebrane w podrozdziale 2.1 można sformułować następujące tezy:

1. Wykazano, iż po okresie pandemii COVID-19 nastąpiło istotne statystycznie obniżenie poziomu sprawności motorycznej wśród dzieci i młodzieży w większości analizowanych testach sprawnościowych, co może być skutkiem obniżonego poziomu aktywności fizycznej w okresie pandemii COVID-19.
2. Wykazano, iż po okresie pandemii koronawirusa nastąpił wzrost wartości niedowagi, prawidłowej masy ciała oraz nadwagi w większości kategoriach wiekowych. Natomiast, odwrotną tendencję zaobserwowano w częstości występowania otyłości, gdyż większość wyników wykazała spadek wartości wśród obu płci. Zaobserwowane zmiany mogły wynikać z ograniczeń aktywności fizycznej, wydłużonym czasem sedentaryjnym oraz czasem spędzonym przed ekranem.
3. Podczas pandemii koronawirusa nastąpił wzrost zawartości tkanki tłuszczowej wśród badanej młodzieży. Zaobserwowano, zwiększenie się obwodu talii wśród najstarszych badanych oraz wzrost obwodu bioder w większości kategorii wiekowych obu płci w 2022 roku w porównaniu z rokiem 2020. Natomiast, po pandemii w większości kategorii wiekowych u obu płci odnotowano spadek wartości obwodu talii oraz wskaźników WHR i WHtR w porównaniu z badanymi w 2020 r. Zaobserwowane zmiany mogą być związane z modyfikacją nawyków żywieniowych, a także zmianami wynikającymi ze stylu życia w trakcie trwania pandemii wirusa SARS-CoV-2.
4. Wykazano, iż po pandemii COVID-19 nastąpił istotny statystycznie wzrost grubości fałdów skórno-tłuszczowych u obu płci. Badana młodzież charakteryzowała się wyższymi wartościami wskaźnika otłuszczenia tułowia oraz stosunku otłuszczenia kończyn do całkowitej sumy fałdów skórno-tłuszczowych w większości kategorii wiekowych. Odwrotną tendencję zaobserwowano w przypadku wskaźnika otłuszczenia kończyn do tułowia., gdyż w większości grup wiekowych zaobserwowano spadek wartości względem badanej młodzieży przed pandemią koronawirusa. Zaobserwowane zmiany, mogą wynikać z obniżonej aktywności fizycznej, wydłużonym czasem spędzonym w pozycji siedzącej oraz czasem spędzonym przed ekranem.
5. Wykazano, zróżnicowane zmiany w wartościach masy mięśniowej wśród badanej populacji, porównując wyniki przed i po pandemii COVID-19. Dziewczęta, badane w 2022 roku charakteryzowały się niższymi wartościami masy mięśniowej,

w porównaniu z rówieśniczkami badanymi w 2020 r. Natomiast, chłopcy z 2022 r. charakteryzowali się wzrostem masy mięśniowej w większości grup wiekowych, w porównaniu z badanymi z 2020 r. Zaobserwowane zmiany mogą być spowodowane łagodzeniem obostrzeń lub z naturalnych różnic rozwojowych związanych z dymorfizmem płciowym.

6. Ważne jest, aby w szkołach podstawowych kształtować wzorzec prawidłowego poziomu aktywności fizycznej, która wpływa na skład ciała oraz kształtowanie sprawności motorycznej wśród dzieci i młodzieży.
7. Wyniki niniejszych badań stanowią cenne źródło wiedzy, które może być pomocne w przypadku ponownego wystąpienia zagrożenia epidemiologicznego.
8. Warto rozważyć, wdrożenie programów profilaktycznych w placówkach szkolnych, mających na celu zapobieganie obniżonej aktywności fizycznej oraz niezdrowych wzorców żywieniowych wśód dzieci i młodzieży, które nasiliły się w czasie trwania pandemii COVID-19.

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Załącznik nr 1.

Publikacja 1

Artymiak P, Żegleń M, Kryst Ł.

Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic.

J Phys Act Health 2024, 13;21(5):500-507. https://doi.org/10.1123/jpah.2023-0577

Journal of Physical Activity and Health, (Ahead of Print)
https://doi.org/10.1123/jpah.2023-0577

First Published Online: Mar. 13, 2024

Human Kinetics
ORIGINAL RESEARCH

Analysis of Changes in Physical Fitness in Children and Adolescents (11–15 Years) From Kraków (Poland) During COVID-19 Pandemic

Paulina Artymiak,[1] Magdalena Żegleń,[2] and Łukasz Kryst[1]
[1]Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Education, Kraków, Poland;
[2]Pain Research Group, Institute of Psychology, Jagiellonian University, Kraków, Poland

Background: The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has posed a threat to society worldwide. The aim of the study was to analyze changes in the physical fitness of 11- to 15-year-olds during the COVID-19 pandemic. ***Methods:*** Cross-sectional research was conducted in randomly selected schools in Kraków (Poland) during the years 2020 and 2022. The study group included 1635 adolescents aged 11–15 years. The results of fitness tests such as flexibility, standing broad jump, handgrip strength, overhead medicine ball throw, shuttle run (10 × 5 m), and 30-second sit-ups were analyzed. Body height and weight measurements were also taken. The standing broad jump and handgrip strength were normalized. A statistical analysis was performed to compare the differences between groups using 2-way analysis of variance with the Tukey HSD post hoc test or Kruskal–Wallis test. ***Results:*** The test results revealed a deterioration decrease in sit-ups, standing broad jump, shuttle run, and normalized standing broad jump in both sexes. Furthermore, the test results among girls showed a decrease in overhead medicine ball throw and flexibility. An increase in test results of both sexes was noticed in handgrip strength of the right and left hand. Among boys in 2022, the results were better in the flexibility test and overhead medicine ball throw compared with their peers from 2020. ***Conclusion:*** This study indicates a decrease in overall physical fitness in adolescents. The observed results may be associated with a decrease in physical activity, changes in nutrition, and restrictions imposed during the COVID-19 pandemic.

Keywords: coronavirus, physical activity, SARS-CoV-2

The COVID-19 pandemic caused by the SARS-CoV-2 virus has posed a global threat to human health, lifestyle, social interactions, and the economy in the world.[1–3] When the World Health Organization (WHO) declared COVID-19 a global pandemic in March 2020, decisive precautions were taken to limit the rapid spread of the virus. One of the main strategies were social distancing and isolation (home quarantine), which involved the closure of all facilities and places where large numbers of people could gather (schools, parks, playgrounds, swimming pools, shopping centers, and gyms).[2,4–6] Society was forced to stay at home, disrupting their daily routine and regular physical activity, as long-term mandatory home restrictions pose a significant challenge to maintaining proper levels of physical fitness.[1]

It is widely recognized that physical activity confers numerous benefits for the physical and mental health of children and adolescents. Among the most commonly cited advantages are improvements in physical fitness, cardiovascular and musculoskeletal fitness, quality of life, and maintenance of healthy body weight.[2,6,7] Additionally, it contributes to physical abilities, including speed, agility, flexibility, muscle strength, coordination, and muscular endurance. Moreover, high levels of physical fitness and regular physical activity established in childhood and adolescence can determine health in adulthood.[2,8] However, limited physical activity and a sedentary lifestyle resulting from COVID-19-related restrictions may have increased the risk of diseases such as diabetes, hypertension, respiratory, and cardiovascular diseases.[1,9]

The WHO has provided clear guidelines regarding the minimum amount of moderate to vigorous physical activity for children and youth necessary to maintain proper health and fitness. For example, children and adolescents are recommended to engage in at least 60 minutes of moderate to vigorous physical activity per day, 7 times a week.[9,10] Unfortunately, many studies have shown that children do not meet these requirements. Social distancing measures imposed by the coronavirus pandemic may have deepened this problem even more. Cohort studies conducted among Greek adolescents in 2016–2017 and 2018–2019 before the pandemic and in 2020–2021 after the coronavirus pandemic showed a deterioration in results of physical tests, such as broad jump, 30-m sprint, and agility among both sexes. It was also suggested that the 5-month isolation caused by the SARS-CoV-2 pandemic had a negative impact on the overall physical fitness of the examined adolescents. A significant decrease in physical activity among young people has been observed, increasing the likelihood of developing cardiovascular and metabolic diseases.[11] Similar results of a decline in physical fitness have been observed in Chinese adolescents, as there has been a decrease in explosive strength tests and aerobic capacity.[12] Unfortunately, social distancing measures have resulted in a reduction in physical activity and an increase in sedentary time, which may lead to a potential wave of negative health consequences associated with physical health in the post-COVID-19 period.[5]

The aim of the study was to analyze changes in the physical fitness of 11- to 15-year-olds from Kraków during the COVID-19 pandemic.

Materials and Methods

The study of Kraków's adolescents was conducted in randomly selected primary schools in 4 districts of the city (Śródmieście, Podgórze, Krowodrza, and Nowa Huta). The cross-sectional studies were conducted in the years 2020 and 2022; thus, the collected

Artymiak https://orcid.org/0000-0002-7291-0121
Żegleń https://orcid.org/0000-0001-6028-8905
Kryst (lkryst@poczta.onet.pl) is corresponding author, https://orcid.org/0000-0001-6938-192X

data covered the period before and after the COVID-19 pandemic. All procedures contributing to this work complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Declaration of Helsinki of 1975, as revised in 2008, and were approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022). In addition, consent for the study was obtained from school principals. The written consent of the parents/legal guardians and the verbal consent of the participants themselves given before the study were necessary for inclusion in the study group. A possible exclusion from participation was based on the lack of consent of a parent/legal guardian, the participant, or information about contraindications to physical activity.

The study group included adolescents aged 11–15 years old. The total sample size was 1635 people (including 1045 in 2020 and 590 in 2022). The number of individuals in particular age categories and series are presented in Table 1. All participants were divided by age and sex. Calendar age was calculated as the difference between the date of birth and the date of examination and expressed as a decimal fraction. In addition, the exact calendar age, the range of which was 10.50 to 15.49, allowed to classify each subject into one of 5 age groups.

Physical fitness was determined using the EUROFIT test (1993),[13] which was modified to adapt it to the methods of tests carried out in previous years. The tests included:

1. Standing broad jump (explosive power of the lower limbs)—performed twice, each time measured to the heel of the tested person with a measuring tape (with an accuracy of 1 cm); the length of both jumps was recorded, and the longer one was used in the analysis of the results.
2. Handgrip strength (static force)—maximum hand strength measured with a dynamometer with an adjustable handle, suitable for use in the pediatric population (Baseline, USA, with an accuracy of 1 kg); the measurement was performed twice for each hand, and both were recorded, with the best result used for the analysis of the results.
3. Overhead medicine ball throw (upper limbs muscle strength)—2 kg medicine ball, performed twice; subjects stood on a designated line and threw the ball over their heads; the distance was measured with an nonelastic tape with an accuracy of 1 cm; a greater distance was used to analyze the results.
4. Shuttle run (speed and agility)—(10 × 5 m); the subjects ran as fast as possible to the second line 5 m away from the starting line and returned to the starting line 10 times at the signal of the researcher; time was measured with a stopwatch with an accuracy of 0.01 second.
5. Flexibility test—the subjects stood on a specially prepared platform and performed a maximum bend of the torso forward from a standing position, which was measured with an inelastic tape attached to the platform with an accuracy of 1 cm; the test was performed twice, and the better result was used for the analysis.
6. Sit-ups—the subjects were in a seated position with their hands crossed on their chest and performed as many sit-ups as possible from a lying position in 30 seconds, touching the mattress with their backs and chest to their knees, with time measured by stopwatch with 0.01 second precision.

All fitness tests were carried out in the morning and were preceded by a warm-up. The adolescents were dressed in gym clothes and sports shoes.

The anthropometric data and motor skills obtained in this study during the winter–spring (February–May) of 2022 were subjected to a comparative analysis with the results of the "Child of Kraków 2020" project, conducted in the winter–spring of 2020, just before the COVID-19 pandemic began.

Body height was measured using an anthropometer, according to Martin's technique (GPM), with an accuracy of 1 mm, and body weight was measured with an electronic scale (Tanita, UM-076, with an accuracy of 0.1 kg). Body mass index (BMI) was determined according to the formula: body weight/height^2, where body weight was expressed in kilograms and body height in meters.

Additionally, socioeconomic characteristics were collected using a survey questionnaire that was completed by the parents of the studied children in 2020.

Moreover, some of the results of the fitness tests were normalized so that the results of adolescents with different body proportions could be compared.

The results of right and left handgrip strength (normalized handgrip strength = handgrip strength/body weight) and standing broad jump (normalized standing broad jump = standing broad jump/body height) were normalized.

To determine if the distribution of a given feature was normal, a Shapiro–Wilk test was used. Based on this, the appropriate test was selected. A statistical analysis was performed to compare the differences between groups using 2-way analysis of variance with the Tukey HSD test or Kruskal–Wallis test.

Statistical analysis was performed using Statistica (version 13.3).

Table 1 Number of Children Included the Sample

Age category/y	2020		2022	
	Girls	Boys	Girls	Boys
11	165	111	94	72
12	104	108	77	79
13	83	111	53	76
14	93	77	44	46
15	100	93	18	31
Total	1045		590	
	1635			

Results

Characteristics of Anthropometric Measurements and Socioeconomic Conditions

Basic anthropometric characteristics (body height and weight, and BMI) were presented in Table 2. Additionally, a description of the socioeconomic conditions was made based on information regarding the place of birth, education, and position of the parents, as well as the family structure in the study group. The majority of parents were born in medium and large cities, suggesting that the surveyed group primarily comes from urban areas. In terms of education, the prevailing number of respondents holds intermediate to higher education, potentially influencing their educational levels and professional opportunities. The occupational positions of parents indicate that most of them hold positions associated with intellectual work. This may impact the financial stability of the family, which is a significant aspect of socioeconomic conditions. Regarding the upbringing of children, the majority are raised within the framework of marriage. This could influence their emotional and

Table 2 Mean ($\bar{x}$) and SD of Body Height, Body Weight, and BMI in Particular Age Categories

	Body height, cm				Body weight, kg				BMI, kg/m^2			
	2020		2022		2020		2022		2020		2022	
Age category, y	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Girls												
11	146.21	7.47	146.85	7.38	38.83	8.96	38.52	7.29	17.98	2.81	17.71	2.41
12	152.88	7.27	154.97	7.22	44.84	8.31	45.05	9.86	19.09	2.74	18.60	2.94
13	158.34	5.61	159.69	5.99	49.18	9.38	49.26	8.32	19.59	3.10	19.26	2.86
14	161.57	7.33	160.68	7.22	55.73	9.04	49.49	12.71	21.10	3.29	19.41	3.23
15	164.17	5.57	164.47	6.81	57.14	11.04	56.31	10.61	21.49	4.08	20.75	3.26
Boys												
11	146.85	7.09	148.15	6.24	40.49	8.92	41.37	9.51	18.64	3.12	18.71	3.37
12	153.56	8.36	153.46	7.57	46.32	10.88	44.39	9.23	19.45	3.39	18.72	2.89
13	159.41	7.50	160.92	8.97	51.36	11.27	51.35	10.80	20.10	3.57	19.72	3.21
14	168.69	8.40	168.68	9.35	57.87	12.12	58.31	13.79	20.22	3.19	20.27	3.63
15	173.49	6.86	171.90	6.88	63.88	13.67	64.68	10.84	21.14	3.89	21.54	2.95

Abbreviation: BMI, Body Mass Index.

Table 3 Percentage Values of the Analyzed Socioeconomic Parameters of the Parents of the Surveyed Adolescents Population From Kraków

Mother's %	Place of birth	Father's %
10.36	Village	9.85
10.00	City ≤ 10,000	11.74
20.00	City ≤ 100,000	18.95
59.64	City > 100,000	59.64
	Work position	
80.00	Intellectual work	69.20
17.54	Physical work	30.43
2.46	Without an occupation	0.36
	Education	
—	Primary education	2.55
5.30	Vocational education	13.87
14.13	Secondary technical	16.06
11.66	Secondary general education	8.76
68.90	Higher education	58.76
	Raises a child/legal guardian	
Marriage		80.90
Single mother		9.38
Other		9.72

social stability, constituting a crucial element in the analysis of socioeconomic conditions (Table 3).

Physical Fitness

Girls

Among girls in most of the age groups, a decrease in flexibility was observed. Among 11- and 13-year-olds, there was an increase in flexibility compared with girls surveyed in 2020. An analogous decline occurred in the case of the overhead medicine ball throw and the standing broad jump (Tables 4 and 5). In addition, there was a decline in the results of the normalized standing broad jump. Though, the differences in the results of the described tests were not statistically significant. There was also a decrease in the number of sit-ups performed in 30 seconds, with statistically significant differences at 11 and 13 years of age. In addition, an increase of the shuttle run time was observed, which was statistically significant in all age groups (Table 4). In addition, an increase in the handgrip strength of the right and left hand was noted. (Results were statistically significant in 11- and 12-year-olds; Table 5) Moreover, the trend continued after normalization of strength for the body weight and was still statistically significant in most age groups (11- to 14-year-olds—right hand, 11-, 12-, and 14-year-olds—left hand; Table 6).

Boys

There was an increase in flexibility among boys, with a statistically significant difference among the 11-year-olds. The trend was opposite in 12-year-old boys. A similar trend was noted for the overhead medicine ball throw—11-, 12-, and 15-year-old boys examined in 2022 gained better results compared with peers from the 2020 cohort (statistical significance in 11-year-olds). Similar to the girls, an increase of the shuttle run time was observed, which was statistically significant across all age groups (Table 4). In addition, a statistically significant increase in the handgrip strength of the right and left hand was observed in all age groups. The opposite trend was noted for the right hand in the group of 12-year-olds (Table 5). An increase in the normalized handgrip strength of the right and left hand was also observed among 11- to 13-year-olds with a simultaneous decrease in the group of 14- to 15-year-old boys. (Differences were significant among 11-year-olds and 14-year-olds; Table 6) As among girls, in most of the age groups, there was a significant decrease regarding the number of sit-ups performed in 30 seconds (Table 4). Only among the oldest boys, the trend was the opposite. In addition, a decrease in the results of the standing broad jump was observed among 12-year-old and 14-year-old boys (Table 5). Additionally, in most of the age groups, there was a decrease in the standardized standing broad jump compared with boys examined in 2020. The differences were statistically significant only among 14-year-olds.

Table 4 Mean Values of the Analyzed Parameters and Their Differences Between Research of 2020 and 2022 Within Age Category

Age category, y	Flexibility, cm					Overhead medicine ball throw, cm					Shuttle run, s					Sit-ups, rep				
	2020		2022		2022 vs 2020	2020		2022		2022 vs 2020	2020		2022		2022 vs 2020	2020		2022		2022 vs 2020
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Girls																				
11	49.41	8.93	50.01	7.98	0.60	408.05	105.48	400.09	103.70	−7.96	21.81	2.82	23.83	2.34	2.02***	22.20	4.23	20.39	4.90	−1.82***
12	49.82	8.30	48.88	8.19	−0.94	485.61	98.90	463.38	122.82	−22.23	21.45	3.25	23.25	2.51	1.80***	22.55	3.58	21.29	4.24	−1.26
13	50.78	8.71	53.72	8.75	2.93	516.24	123.58	541.27	136.63	25.03	20.12	2.12	22.40	2.30	2.28***	24.13	4.49	22.40	4.73	−1.73*
14	52.23	8.22	51.97	7.96	−0.26	590.69	126.88	529.58	163.26	−61.12	20.23	2.28	23.28	2.97	3.05***	22.70	3.70	23.05	4.64	0.35
15	53.51	9.39	52.69	7.80	−0.81	592.64	153.40	670.69	238.13	78.04	20.76	2.60	23.09	2.26	2.33***	22.59	4.23	24.53	5.04	1.94
Boys																				
11	43.09	7.72	47.56	7.86	4.47***	473.56	115.78	523.18	133.94	49.62*	20.50	2.64	22.54	2.79	2.04***	23.28	4.77	21.48	6.01	−1.80*
12	45.03	7.17	44.39	8.51	−0.64	534.07	160.21	541.11	144.64	7.04	19.80	2.64	22.23	2.62	2.43***	24.49	4.69	21.93	4.56	−2.56***
13	43.72	7.73	46.04	8.80	2.32	632.86	148.04	602.31	159.56	−30.55	19.47	2.30	22.63	2.62	3.16***	25.65	4.69	23.13	4.89	−2.52***
14	42.93	8.92	46.19	9.17	3.26	787.23	165.89	699.94	290.39	−87.30	18.57	1.89	22.57	2.90	4.00***	25.91	5.01	23.79	4.13	−2.12*
15	47.13	9.46	48.39	10.03	1.26	809.60	286.59	866.55	239.68	56.95	18.17	2.40	20.92	2.64	2.74***	26.84	5.49	27.78	6.21	0.94

*Statistically significant $P < .05$. ***Statistically significant $P < .001$.

Table 5 Mean Values of the Analyzed Parameters and Their Differences Between Research of 2020 and 2022 Within Age Category

	Standing broad jump, cm					Handgrip strength (right), kg					Handgrip strength (left), kg				
	2020		2022		2022 vs	2020		2022		2022 vs	2020		2022		2022 vs
Age category, y	Mean	SD	Mean	SD	2020	Mean	SD	Mean	SD	2020	Mean	SD	Mean	SD	2020
Girls															
11	137.71	23.66	137.40	24.36	–0.31	15.47	4.12	16.60	4.12	1.13*	14.15	3.91	15.33	4.26	1.18*
12	142.58	24.40	142.07	24.22	–0.51	18.57	4.55	20.66	4.76	2.09*	16.89	4.17	18.84	4.37	1.96**
13	153.00	25.25	151.66	26.95	–1.34	21.33	4.47	22.04	5.13	0.71	19.22	4.36	21.00	5.24	1.78
14	149.83	26.76	152.98	26.82	3.15	22.46	4.81	23.68	6.11	1.22	20.96	4.75	21.98	5.58	1.02
15	154.46	25.06	164.56	23.38	10.10	25.32	5.21	26.06	6.22	0.74	23.45	5.21	24.44	6.53	0.99
Boys															
11	144.25	22.40	147.60	23.92	3.35	16.60	4.01	18.39	4.11	1.79**	15.23	3.91	17.76	5.73	2.53**
12	155.92	26.56	152.51	24.72	–3.41	19.83	4.96	20.52	5.17	0.69*	18.42	5.28	18.30	4.73	–0.12
13	161.77	29.95	163.50	28.70	1.73	22.36	5.09	24.47	6.00	2.11	21.23	5.80	21.96	6.17	0.73
14	178.97	30.84	177.02	35.91	–1.95	26.77	5.80	27.96	7.84	1.19***	24.75	5.61	25.85	7.19	1.09
15	195.24	31.70	201.16	27.32	5.92	30.90	7.48	37.45	8.64	6.55	29.26	7.52	35.60	8.61	6.34***

*Statistically significant $P < .05$. **Statistically significant $P < .01$. ***Statistically significant $P < .001$.

Table 6 Mean Values of the Analyzed Parameters and Their Differences Between Research of 2020 and 2022 Within Age Category

	Standing broad jump—normalized					Handgrip strength (right)—normalized					Handgrip strength (left)—normalized				
	2020		2022		2022 vs	2020		2022		2022 vs	2020		2022		2022 vs
Age category, y	Mean	SD	Mean	SD	2020	Mean	SD	Mean	SD	2020	Mean	SD	Mean	SD	2020
Girls															
11	0.94	0.16	0.94	0.17	0.00	0.40	0.10	0.44	0.10	0.03*	0.37	0.09	0.40	0.10	0.03*
12	0.93	0.16	0.92	0.17	–0.01	0.42	0.10	0.47	0.09	0.04*	0.38	0.09	0.43	0.10	0.04**
13	0.97	0.16	0.95	0.17	–0.02	0.44	0.10	0.46	0.10	0.01*	0.40	0.09	0.43	0.10	0.03
14	0.93	0.16	0.95	0.16	0.02	0.41	0.08	0.47	0.10	0.06***	0.38	0.08	0.44	0.09	0.06***
15	0.94	0.15	1.00	0.14	0.06	0.45	0.11	0.47	0.12	0.02	0.42	0.11	0.44	0.11	0.02
Boys															
11	0.91	0.15	1.00	0.17	0.09***	0.35	0.13	0.46	0.11	0.10***	0.33	0.13	0.44	0.13	0.11***
12	0.98	0.17	0.99	0.16	0.02	0.41	0.15	0.47	0.12	0.06***	0.38	0.15	0.42	0.11	0.04**
13	1.03	0.21	1.01	0.16	–0.02	0.47	0.18	0.48	0.10	0.01	0.45	0.17	0.43	0.10	–0.02
14	1.14	0.21	1.05	0.20	–0.09**	0.56	0.15	0.49	0.11	–0.07*	0.52	0.15	0.45	0.10	–0.06*
15	1.22	0.22	1.17	0.16	–0.05	0.65	0.23	0.59	0.12	–0.06	0.61	0.21	0.56	0.12	–0.05

*Statistically significant $P < .05$. **Statistically significant $P < .01$. ***Statistically significant $P < .001$.

Discussion

The results of current research suggest that social distancing measures applied during the COVID-19 pandemic have significantly affected the physical fitness of 11- to 15-year-olds from Kraków. There was a significant decrease in shuttle run and sit-up results for both sexes. Additionally, among girls, there was a decrease in results of medicine ball throw, flexibility, and standing broad jump. Furthermore, among boys, a decrease was observed in standing broad jump results. The conducted research also showed an increase in handgrip strength for both sexes in all age categories. Moreover, among boys, there was an increase in medicine ball throw and flexibility test results in most age groups.

In Poland, a decrease in physical fitness among children and adolescents aged 8–18 years old was already observed before the coronavirus pandemic. This was demonstrated in the study of the Kraków population conducted between 2010 and 2020, where a decrease in flexibility, overhead medicine ball throw, and grip strength for both sexes was observed. At the same time, better results were observed in the shuttle run among boys tested in 2020 compared with their peers examined in 2010.[14]

Physical fitness is an important determinant of current and future health for children and adolescents.[15,16] High levels of musculoskeletal fitness among young people are generally associated with improved health status and reduced risk of chronic diseases.[17] In addition, physical activity is recognized as one of

the fundamental prescriptions for preventing mental illnesses, cardiovascular diseases, and improving physical fitness.[18]

Indeed, preliminary studies suggest that social distancing measures resulting from coronavirus pandemic restrictions have had a negative impact on the physical fitness of young people.[2,11,15] Studies conducted among Croatian youth aged 15–17 years showed a decrease in muscular fitness in terms of the number of sit-ups and a 600-m run, analyzing results before and after the COVID-19 pandemic. Furthermore, a greater decrease in muscular fitness was observed among boys in this study.[2]

A similar decline in physical fitness during isolation caused by the COVID-19 pandemic was observed in the United States among children and adolescents aged 9–14. The results indicate a decrease in the Progressive Aerobic Cardiovascular Endurance Run (–26.7%), sit-ups (–19.4%; 22.7 to 18.3 repetitions, $P < .001$), and push-ups (–35.6%; 7.3 to 4.7 repetitions, $P < .001$). Additionally, the study shows an increase in BMI (+10.6%).[19]

In a recent study by Kidokoro et al,[15] it was observed that children and adolescents aged 10–11 and 13–14 years experienced a decline in physical fitness during the coronavirus pandemic. The decline was noted in the results of 20-m shuttle run and sit-up test.

Similarly, a study conducted among French youth in primary schools showed a decrease in mean (SD) results of standing broad jump (169.9 [142.5] cm vs 135.2 [31.4] cm), medicine ball throw (297.3 [81.1] cm vs 249 [52] cm), shuttle run (26.9 [6.2] s vs 30.9 [5.4] s) as well as in VO_2max when comparing prepandemic results to these obtained during the COVID-19 pandemic.[20] Furthermore, López-Bueno et al[21] showed that restrictions caused by the SARS-CoV-2 pandemic have reduced cardiovascular fitness among girls. Also among Austrian children aged 7–10 years, a decrease in cardiorespiratory fitness was observed, analyzing the results before and after the COVID-19 pandemic.[22]

Additionally, research conducted among children aged 8–10 years from England showed a decrease in sit and reach (–1.8 cm) and shuttle run tests (20 m) (–3 shuttles) when analyzing results after a 12-month lockdown due to the COVID-19 pandemic. Similarly, the sit and reach test, which measures muscle flexibility, showed a decrease from 15.3 to 13.5 cm, indicating a reduction in flexibility among the studied children.[23]

There is no denying that the COVID-19 pandemic and associated restrictions have had a significant impact on the physical fitness of young people. However, not all physical fitness test scores have declined. In the research conducted among the youth in Kraków, some fitness tests did not show any regression. Research revealed an increase in handgrip strength, medicine ball throw, and flexibility test scores during the imposed restrictions due to the COVID-19 pandemic. These results were confirmed in studies conducted among Portuguese children aged 10–18 years, where body composition and aerobic fitness (VO_2max) deteriorated, while neuromuscular fitness showed an increase during the coronavirus pandemic.[17]

Similar results have been observed among Korean adolescents aged 13–15 years. The findings showed a decrease in the results of shuttle run, handgrip strength, and 50-m sprint among boys, while flexibility increased. On the other hand, girls exhibited decreased flexibility, but an increase in handgrip strength.[24]

The differences in studies regarding the impact of the COVID-19 pandemic on physical fitness may stem from variations in government decisions regarding the closure of educational institutions, limitations on physical activity, and the applied research methodology. During the lockdown caused by the SARS-CoV-2 virus, a negative influence on the results of physical fitness tests, such as shuttle run or sit-ups, was observed compared with other fitness tests, such as handgrip strength.[15]

Systematic reviews document the positive impact of physical activity on cardiovascular-respiratory fitness and muscle strength. Low cardiovascular-respiratory fitness can have a negative effect on population health by increasing BMI and the risk of developing metabolic syndrome. Studies conducted on Austrian children aged 7–10 years have shown a decline in cardiovascular-respiratory fitness and an increase in BMI SD score values and waist circumference. Analyzing the results before and after the COVID-19 pandemic, the number of children with overweight or obesity increased from 15.0% to 21.2%.[22]

The results of these studies suggest that young people may have experienced circumstances conducive to weight gain during the pandemic. Factors such as stress, irregular meal consumption, limited physical activity, and increased screen time may have contributed to the increase in body weight. Data from the Ambulatory Electronic Medical Records database in the United States confirm this trend, showing a significant increase in BMI among children and adolescents aged 2–19 years after the pandemic, particularly in the case of overweight and obesity.[25] The closure of educational institutions during the pandemic may be related to these findings, as it disrupted the rhythm of organized physical activity and access to healthy meals in school cafeterias.[25,26]

A sedentary lifestyle and lack of physical activity have a negative impact on physical fitness levels and contribute to the risk of developing many chronic diseases.[16,27] Unfortunately, most teenagers fail to meet the daily physical activity requirements recommended by the WHO. Although it is widely known that the level of physical activity is one of the main factors affecting physical fitness.[14,28,29] Disturbing changes in physical activity have been described even before the COVID-19 crisis. Prepandemic studies showed a decrease in the 60 minutes of daily physical activity recommended by the WHO.[29]

Studies conducted among Spanish children showed a decrease (mean [SD]) in total physical activity (–91 [55] min/d, $P < .001$) along with an increase in screen time (1.9 [2.6] h/d, $P < .001$) compared with the results from before the lockdown. The frequency of children sitting in front of monitor screens for more than 2 hours a day also increased from 66% to 87.7%.[30]

The results of the conducted research indicate that the restrictions imposed during the SARS-CoV-2 virus lockdown had a significant impact on the deterioration of physical fitness among Polish youth, although not all tests showed regression. Both sexes showed a decrease in sit-ups, standing broad jump, normalized standing broad jump, and an increase in the time of the shuttle run test. Among girls, a decrease was also observed in the medicine ball throw and flexibility tests. The worsening results of physical fitness tests may be caused by reduced physical activity, remote learning, and staying at home during the lockdown. It is also worth emphasizing that discrepancies in the results of current research may be related to significant changes in physical development typical of adolescence, such as body height and biological maturity, which affect muscle strength and body structure. Additionally, existing differences between cohorts may be due to age-related changes in physical activity habits, which may impact the development of muscle strength. On the other hand, the improvement of some results may be due to physical activity at home or in the yard, as well as the possibility of returning to regular physical activity as restrictions ceased. These results may also correlate with earlier studies that analyzed the secular trend in the physical fitness of children and adolescents aged 8–18 years from Kraków in the years

2010–2020, indicating an improvement in handgrip strength.[14] Additionally, the impact of remote learning on maintaining a fixed hand position while using the keyboard and mouse may affect hand muscles. Regular use of these devices can support hand stability and control of movements. Special exercises, such as squeezing a ball in your hand, can be performed even while working at the computer, further influencing the improvement of handgrip strength.[31] The factors mentioned above may influence the improvement of handgrip strength during the COVID-19 pandemic in the results of current research. In future studies, it is worth investigating whether the restrictions introduced during the coronavirus pandemic will have a long-term negative impact on the physical fitness of young people. It is also important to prepare a strategically targeted intervention or preventive program that could help neutralize the effects of reduced physical activity among children and adolescents.

Acknowledgment

This study was sponsored by the University of Physical Education in Kraków (grant number 189/BS/INB/2018, 330/BS/INB/2023).

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(Ahead of Print)

Załącznik nr 2.

Publikacja 2

Artymiak P, Żegleń M, Kryst Ł.

Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic.

Anthropol Anz. 2025, 11;82(1):1-6. https://doi.org/10.1127/anthranz/2024/1746

Anthropol. Anz. 82/1 (2025), 1–6
J. Biol. Clin. Anthropol.
Published online June 14, 2024, published in print February 2025

Article

Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11–15 years) from Kraków (Poland) during COVID-19 pandemic

Paulina Artymiak[1], Magdalena Żegleń[2], Łukasz Kryst[1,*]

[1] Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Education, Kraków, Poland
[2] Pain Research Group, Institute of Psychology, Jagiellonian University, Kraków, Poland
* Corresponding author: lkryst@poczta.onet.pl

With 5 tables

Abstract: In March 2020, the spread of the new coronavirus SARS-CoV-2, triggered a pandemic of acute respiratory distress syndrome among people. The aim of the study was to evaluate the changes in BMI and in the prevalence of overweight and obesity in children and adolescents (11–15-year-olds) from Kraków (Poland) during the COVID-19 pandemic. Two cross-sectional studies were performed in 2020 and 2022 in randomly selected elementary schools in 4 districts of Kraków. The study group was 1572 children between the ages of 11–15 years. BMI (Body Mass Index) was calculated. Participants were grouped using Cole's cut-off points. The statistical significance of differences between the groups was estimated using the two-way ANOVA and Chi^2 test. An increase in the prevalence of underweight and normal weight was observed in both sexes. In girls a decrease in the prevalence of obesity was noted, while in boys, the same tendency was present in some age groups. In girls, a decrease in the prevalence of overweight and in the average BMI was noted; in boys the trend was the opposite. The observed results may be correlated with changes in body composition and restrictions resulting from the lockdown caused by the COVID-19 pandemic.

Keywords: coronavirus; COVID-19; physical activity; BMI; obesity

1 Introduction

It is known that physical activity has significant benefits for children and adolescents. An active lifestyle is necessary to learn fundamental motor skills, to keep optimal body weight and adiposity, as well as the good overall quality of life. On the other hand, decreasing level of physical activity can have negative consequences, including health problems such as obesity, type II diabetes or cardiovascular diseases (Xiang et al. 2020; Yomoda & Kurita 2021; Naville et al. 2022).

In March 2020, when coronavirus SARS-CoV-2 spread all over the world, the WHO (World Health Organization) classified it as a global pandemic. Due to the quick spread of the virus, every country had to implement serious safety measures. Schools, as well as places associated with access to physical activity (pools, gyms and sports halls), parks, forests and playgrounds were closed. Additionally, safety restrictions included wearing masks, social distancing and limiting contact with other people, especially those at the highest risk for the severe course of COVID-19. Restrictions put in place during the pandemic were supposed to slow the spread of infection in society. However, they could also have had an unintentional, negative impact on the physical and psychological health of children and adolescents (Yomoda & Kurita 2021; Naville et al. 2022; WHO 2022). Limitations tied to the restrictions caused a sudden drop in physical activity and an increase in sedentary time, which were partially due to remote education. Moreover, isolation resulting from the pandemic restrictions contributed to an increased risk of mental health problems, especially in youth (Yomoda & Kurita 2021; Naville et al. 2022). It should also be stressed that hypokinesia can lead to an increase in body mass and adiposity and a decrease in muscle mass, thus elevating the risk of cardiovascular and metabolic diseases, even at a relatively young age (Xiang et al. 2020).

A review by Caputo and Reichert shows that the coronavirus epidemic caused a global decrease in physical activity. Additionally, the authors of the review signify the negative impact of these changes on mental health (Caputo & Reichert 2020). Moreover, according to the producers of personal activity monitors and smartwatches, at the end of 2020, there was already a decrease in the number of steps counted

DOI: 10.1127/anthranz/2024/1746
www.schweizerbart.de
0003-5548/2024/1746 $ 1.50

compared to the previous year. The step-count dropped by 7% in Germany, 12% in the USA and 14% in Canada, up to 38% in Spain (TctMD 2020). Likewise, in a study carried out in Shanghai, a decrease in physical activity was observed from 540 to 105 min/week, while screen time increased from 170 to 450 min/week. It is also important to note that during the pandemic, unhealthy eating habits became widespread, including eating more meals, lack of control over the food intake, or more frequent snacking in between meals (Ammar et al. 2020).

Preservation of patterns such as the decrease in physical activity and the unhealthy diet can be particularly dangerous for children and adolescents, whose health habits are still developing (Dunton et al. 2020). In Poland and other countries, studies on the prevalence of underweight, overweight and obesity in children and adolescents during the pandemic are crucial for future generations in terms of pro-health behavior.

The aim of the study was to assess changes in the average BMI (Body Mass Index) and prevalence of overweight and obesity in children and adolescents (11–15 years old) from Kraków within the pandemic period.

2 Materials and methods

The study was conducted in two cross-sectional series in 2020 and 2022 in randomly selected elementary schools located in four of Kraków's districts: Śródmieście, Podgórze, Krowodrza, Nowa Huta. The study was conducted with the consent of the schools' principals. Additionally, the written consent of parents/legal guardians, as well as the verbal consent of the participants themselves, were necessary to include them in the study group.

The study was conducted in accordance with the recommendations of the 1975 Declaration of Helsinki, as revised in 2008 and approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022).

The study group included children and adolescents aged 11–15 years – 1070 participants in 2020 (558 girls and 512 boys) and 593 participants in 2022 (288 girls and 305 boys) (Table 1). Participants were grouped by age and sex. The exact calendar age of the subjects was 10.50–15.49 years. It was calculated as the difference between the date of birth and the date of the study, expressed as a decimal fraction. Calendar age made it possible to classify each participant into one of 5 age groups (e.g., children whose calendar age was between 11.50 and 12.49 years were classified into the 12-years-old category).

Body height was measured with an anthropometer (GPM, Switzerland, accuracy – 1 mm) according to the Martin technique. Body weight was obtained using an electronic scale (Tanita, Japan, model BC-418 accuracy – 0.1 kg). BMI (Body Mass Index) was determined according to the formula: body weight/height^2, where body weight was expressed in kilograms and body height in meters. Additionally, the mean values and standard deviations were calculated for measurements of body height, body weight and BMI in individual age categories (Table 2). Subsequently, the subjects were grouped as underweight, normal weight, or having overweight or obesity according to Cole's cut-off points (Australian Health Survey 2011–13). The utilization of these specific cut-off points enabled uniform and standardized classification of participants based on their BMI, facilitating the comparison of the 2022 results with those from 2020.

Statistical analysis was performed to compare the differences between the groups using two-way ANOVA (Table 3) and Tukey's post-hoc test or Kruskal-Wallis test, depending on the normality of the distribution (assessed with Shapiro-Wilk's test). The Chi^2 test was used to assess the statistical significance of the differences in the prevalence of underweight, overweight and obesity across the age and sex categories.

Statistical analyses were performed using Statistica 13.3 software.

Table 1. Number of children included the sample.

Age category [yrs.]	2020		2022	
	Girls	Boys	Girls	Boys
11	171	115	94	72
12	107	110	78	79
13	87	115	54	77
14	93	79	44	46
15	100	93	18	31
Total	558	512	288	305
	979		593	
	1572			

Table 2. Mean ($\bar{x}$) and standard deviation (SD) of body height, body weight and BMI in particular age categories.

Age category [years]	Body height (cm)				Body weight (kg)				BMI (kg/m²)			
	2020		2022		2020		2022		2020		2022	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Girls												
11	146.21	7.47	146.85	7.38	38.83	8.96	38.52	7.29	17.98	2.81	17.71	2.41
12	152.88	7.27	154.97	7.22	44.84	8.31	45.05	9.86	19.09	2.74	18.60	2.94
13	158.34	5.61	159.69	5.99	49.18	9.38	49.26	8.32	19.59	3.10	19.26	2.86
14	161.57	7.33	160.68	7.22	55.73	9.04	49.49	12.71	21.10	3.29	19.41	3.23
15	164.17	5.57	164.47	6.81	57.14	11.04	56.31	10.61	21.49	4.08	20.75	3.26
Boys												
11	146.85	7.09	148.15	6.24	40.49	8.92	41.37	9.51	18.64	3.12	18.71	3.37
12	153.56	8.36	153.46	7.57	46.32	10.88	44.39	9.23	19.45	3.39	18.72	2.89
13	159.41	7.50	160.92	8.97	51.36	11.27	51.35	10.80	20.10	3.57	19.72	3.21
14	168.69	8.40	168.68	9.35	57.87	12.12	58.31	13.79	20.22	3.19	20.27	3.63
15	173.49	6.86	171.90	6.88	63.88	13.67	64.68	10.84	21.14	3.89	21.54	2.95

Table 3. Results of ANOVA for BMI.

Effect	Girls				Boys			
	SS	MS	F	*p*	SS	MS	F	*p*
Intercept	225873.7	225873.7	23073.41	< 0.001	274753.4	274753.4	24385.32	< 0.001
Cohort	89.2	89.2	9.11	0.003	2.4	2.4	0.22	NS
Age category	763.2	190.8	19.49	< 0.001	547.3	136.8	12.14	< 0.001
Cohort* Age category	71.6	17.9	1.83	NS	27.6	6.9	0.61	NS

3 Results

3.1 Girls

Among girls in most age groups, there was an increase in the prevalence of underweight, which was statistically significant among 14-year-olds. The trend was the opposite in 15-year-old girls. There was also an increase in the percentage of girls characterized by normal weight, except for 12-year-olds, in whom the opposite trend was observed. The prevalence of overweight decreased among girls in all age categories. However, the differences were statistically significant only in 14-year-olds. In the case of obesity, except for 12-year-old girls, a decrease was observed in 2022 compared to the 2020 series (Table 4).

3.2 Boys

Similarly to girls, boys examined in 2022 were characterized by a higher prevalence of underweight than their 2020 peers, except for 12 and 13-year-olds. An increase in the percentage of boys with normal body weight was also observed in most age categories, except for 11 and 15-year-olds. At 11, 12 and 15 years of age, there was an increase in the prevalence of overweight in 2022 compared to the 2020 cohort. In contrast, the prevalence of obesity decreased in most age groups (Table 5).

4 Discussion

The results of the study suggest that after isolation caused by the COVID-19 pandemic, there was an increase in the prevalence of underweight in adolescents of both sexes. Also, an increase in the prevalence of overweight was noted in 11, 12, and 15-year-old boys. Among girls, a reverse trend has been observed in all age categories. In addition, there was a decrease in the percentage of children suffering from obesity. However, this tendency was present only in some age groups of both sexes.

The state of Krakow's population in regards to the body mass status and other parameters before the coronavirus pandemic was not significantly different from proper body weight norms (Woronkowicz et al. 2016; Żegleń et al. 2020; Kryst et al. 2023).

In research conducted in Jordan, an increase in the prevalence of overweight and obesity was noted in children aged 6–12 – pre-pandemic it was 18% and 16.7%, respectively,

Table 4. Number of individuals (percentage) of children in each BMI category in the 2020 and 2022 and their differences (girls).

Age category [yrs.]	Cohort	Underweight n [%]	Change over time [%]	Normal n [%]	Change over time [%]	Overweight n [%]	Change over time [%]	Obesity n [%]	Change over time [%]
11	2020	16 [9.41]	1.22	130 [76.47]	1.18	20 [11.76]	−0.06	4 [2.35]	−1.29
	2022	10 [10.63]		73 [77.65]		11 [11.70]		1 [1.06]	
12	2020	7 [6.54]	8.84	79 [73.83]	−7.17	21 [19.62]	−2.96	1 [0.93]	0.35
	2022	12 [15.38]		52 [66.66]		13 [16.66]		1 [1.28]	
13	2020	7 [8.04]	1.21	70 [80.45]	2.88	6 [6.88]	−1.34	4 [4.59]	−2.74
	2022	5 [9.25]		45 [83.33]		3 [5.55]		1 [1.85]	
14	2020	6 [6.45]	11.73*	65 [69.89]	5.11	19 [20.43]	−15.89*	3 [3.22]	−0.95
	2022	8 [18.18]		33 [75.00]		2 [4.54]		1 [2.27]	
15	2020	10 [10.00]	−4.45	70 [70.00]	18.88	14 [14.00]	−8.45	6 [6.00]	−0.45
	2022	1 [5.55]		16 [88.88]		1 [5.55]		1 [5.55]	
Total	2020	46 [8.24]	4.17	414 [74.19]	1.32	80 [14.33]	−3.99	18 [3.22]	−1.50
	2022	36 [12.41]		219 [75.51]		30 [10.34]		5 [1.72]	

*$p < 0.05$

Table 5. Number of individuals (percentage) of children in each BMI category in the 2020 and 2022 and their differences (boys).

Age category [yrs.]	Cohort	Underweight n [%]	Change over time [%]	Normal n [%]	Change over time [%]	Overweight n [%]	Change over time [%]	Obesity n [%]	Change over time [%]
11	2020	9 [7.82]	1.90	80 [69.56]	−5.68	21 [18.26]	1.18	5 [4.34]	2.60
	2022	7 [9.72]		46 [63.88]		14 [19.44]		5 [6.94]	
12	2020	8 [7.27]	−0.94	75 [69.09]	3.06	20 [18.18]	2.07	6 [5.45]	−4.19
	2022	5 [6.33]		57 [72.15]		16 [20.25]		1 [1.26]	
13	2020	9 [7.82]	−1.33	74 [64.34]	9.86	29 [25.22]	−10.94	3 [2.60]	2.59
	2022	5 [6.49]		57 [74.02]		11 [14.28]		4 [5.19]	
14	2020	3 [3.79]	4.90	57 [72.15]	1.76	17 [21.51]	−6.30	2 [2.53]	−0.43
	2022	4 [8.69]		34 [73.91]		7 [15.21]		1 [2.17]	
15	2020	6 [6.45]	0.00	67 [72.04]	−1.08	15 [16.12]	3.23	5 [5.37]	−2.15
	2022	2 [6.45]		22 [70.96]		6 [19.35]		1 [3.22]	
Total	2020	35 [6.85]	0.69	353 [69.08]	1.74	102 [19.96]	−2.26	21 [4.10]	−0.17
	2022	23 [7.54]		216 [70.82]		54 [17.70]		12 [3.93]	

and after lockdown, both numbers increased to 24.1%. In addition, in adolescents (aged 13–17) the prevalence of overweight decreased from 23.3% to 20.7%. In the same population, the prevalence of obesity increased from 12.9% to 16.4% during the lockdown caused by the COVID-19 pandemic (Al Hourani et al. 2022).

In a review of literature by La Fauci it was observed that children aged 8–12 years and 6–11 years were characterized by an increase in body mass during the COVID-19 pandemic. The review also showed a greater weight gain in boys than in girls. This is likely due to prolonged stress, increased sedentary time, and unhealthy eating habits, which may contribute to weight gain and obesity resulting from the restrictions associated with the COVID-19 pandemic (La Fauci et al. 2022).

Additionally, studies conducted among youth in China revealed an increase in the prevalence of overweight and obesity, as well as elevated BMI during the Covid-19 pandemic (Yang et al. 2020; Jia et al. 2021). In Greece, extensive questionnaires allowed for the evaluation of time spent on physical activity, in front of screens as well as the quality of sleep and body weight. 35% of parents observed that their children (aged 2–18) gained weight, and 66.9% of surveyed adults stated that their children's physical activity decreased during the lockdown caused by the COVID-19 pandemic (Androutsos et al. 2021). Also the deterioration of physical fitness was noted – in the Kraków population, it was observed that physical fitness among adolescents worsened after the pandemic period (Artymiak et al. 2024). Also,

according to the data from several studies, it was observed that social distancing and home isolation associated with the coronavirus pandemic had a significant impact on public health (Di Rezno et al. 2020). In Palestine, 41.7% of young people confirmed weight gain caused by increased consumption of fried foods, sweets and sweet drinks during the lockdown (Allabadi et al. 2020).

Changes in lifestyle during the COVID-19 pandemic may have potentially contributed to an increase in overweight and obesity. In the United States, parents of children and adolescents struggled with obstacles related to virtual learning, consuming processed and high-calorie foods, and limitations on physical activity, which were all associated with the COVID-19 pandemic. Restrictions on the transmission of the SARS-CoV-2 virus likely contributed to a worsening of childhood obesity, as the average prevalence of obesity increased from 13.7% before the pandemic (June–December 2019) to 15.4% during the pandemic (June–December 2020) (Jenssen et al. 2021).

Restrictions caused by the COVID-19 pandemic have disrupted the daily routines of children and adolescents, resulting in changes in physical activity and dietary behaviors (Stavridou et al. 2021).Cohort studies conducted in the United States based on electronic medical records from Kaiser Permanente Southern California (KPSC) have shown that during the coronavirus pandemic, youth experienced an increase in body mass compared to pre-pandemic analyses. The largest changes deviating from the median BMI for age were observed in children aged 5–11 years (BMI increased by 1.57) compared to adolescents aged 12–15 years (0.91) and 16–17 years (0.48) (Woolford et al. 2021).

An increase in BMI and in the prevalence of overweight and obesity in children during the COVID-19 pandemic can be caused by many factors. A review of the literature shows that the most common factors are: decreased physical activity, increased sedentary time and improper diet. Also, in research carried outby Neville et al. (2022), there was a decrease in physical activity by 20%. In addition, time spent on moderate to vigorous physical activity decreased by 28%, when analyzing results before and after the pandemic (Neville et al. 2022). The cause may be the lack of organized activities, which were cancelled during the COVID-19 pandemic (Tulchin-Francis et al. 2021).

The current research shows that isolation caused by the COVID-19 pandemic could have caused changes in body mass in adolescents. The changes may be caused by the restrictions, which did not allow for moving around, gathering in larger crowds and enforced closing of gyms and schools. In the Czech Republic, the lockdown caused by the COVID-19 pandemic has contributed to significant changes in body composition among boys aged 11–18. In the study, there were no significant changes in body weight and BMI. However, an increase in body fat and visceral adipose tissue area was observed, while skeletal muscle mass decreased significantly. The reason for these changes is a significant decrease in physical activity among the surveyed youth, which was related to the restrictions resulting from the coronavirus pandemic. In addition, a decrease in skeletal muscle mass may cause limitations in various types of physical activity in the future (Kutac et al. 2022).

This study has several limitations. Firstly, due to the prolonged isolation caused by the COVID-19 pandemic, a limited number of students from the oldest age group consented to participate in the study. Secondly, due to the long break in school activities caused by the pandemic, it may have led to discomfort for some students with higher body mass during anthropometric measurements. This phenomenon could have affected the representativeness of the sample in the context of Body Mass Index.

The results of the current research showed an increase in the prevalence of underweight and normal body weight, while the prevalence of obesity decreased in both sexes. In addition, a decrease in overweight and BMI values was observed among girls, while an opposite tendency was noted among boys. A slight increase in the prevalence of underweight and obesity and a decrease in overweight and obesity depending on the age category and sex may be related to changes in body composition because the amount of fat and muscle tissue affects body weight. The described changes may potentially be associated with the restrictions imposed during the COVID-19 pandemic. In future research, it is worth investigating whether the restrictions resulting from the SARS-CoV-2 pandemic contributed to the development of long-term negative habits related to weight gain. In addition, it will also be beneficial to investigate whether the described problems are related to physical activity.

Conflict of interest: The authors have no conflicts of interest to declare.

Ethical approval: The study was conducted in accordance with the recommendations of the 1975 Declaration of Helsinki, as revised in 2008 and approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022).

Acknowledgements: This study has been sponsored by the University of Physical Education in Kraków (grant number 189/BS/INB/2018, 330/BS/INB/2023).

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Manuscript received: July 8, 2023
Revisions requested: April 22, 2024
Revised version received: April 23, 2024
Manuscript accepted: April 23, 2024

Załącznik nr 3.

Publikacja 3

Artymiak P, Żegleń M, Kryst Ł.

The effect of the COVID-19 pandemic lockdown on the distribution of fattissue and skinfoldthickness in adolescents from Kraków (Poland).

Pediatr Obes. 2024, 19(10):e13160. https://doi.org/10.1111/ijpo.13160

Received: 13 February 2024 | Revised: 21 July 2024 | Accepted: 29 July 2024
DOI: 10.1111/ijpo.13160

ORIGINAL RESEARCH

Pediatric OBESITY WILEY

The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland)

Paulina Artymiak[1] | Magdalena Żegleń[2] | Łukasz Kryst[1]

[1]Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Education, Kraków, Poland
[2]Pain Research Group, Institute of Psychology, Jagiellonian University, Kraków, Poland

Correspondence
Łukasz Kryst, Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Education, 31-571 Kraków, Poland.
Email: lkryst@poczta.onet.pl

Funding information
Akademia Wychowania Fizycznego im. Bronisława Czecha w Krakowie, Grant/Award Numbers: 189/BS/INB/2018, 330/BS/INB/2023

Summary

Background: The COVID-19 pandemic has significantly changed the lifestyle and dietary habits of societies worldwide. The aim of the study was to assess changes in the distribution of fat tissue and skinfold thickness in adolescents (aged 11–15) from Kraków during the COVID-19 pandemic period.

Methods: Two cross-sectional studies conducted in 2020 and 2022 (before and after the pandemic) involved 1662 adolescents from the Kraków population. Skinfold thickness measurements were taken. The trunk adiposity index, limbs-to-trunk fat ratio and limbs-to-total skinfold ratio were calculated. Statistical analysis employed a two-way ANOVA, Tukey's HSD test and the Kruskal–Wallis test, depending on the normality of the distribution.

Results: Higher skinfold thicknesses were observed in the majority of age groups in both sexes from the 2022 cohort in comparison with the 2020 cohort. Additionally, higher values of the trunk adiposity index and the limbs-to-total skinfold ratio in most age groups were observed. However, an inverse trend was observed in the limbs-to-trunk fat radio.

Conclusions: The introduced restrictions such as lockdown, remote learning, reduced physical activity and changes in dietary habits could have influenced the distribution of fat tissue and skinfold thickness amongst adolescents from Kraków.

KEYWORDS
adolescents, coronavirus, obesity, skinfold thickness

1 | INTRODUCTION

In December 2019, a new coronavirus (COVID-19) belonging to the betacoronavirus family was detected in the city of Wuhan (China) and has rapidly spread around the world.[1–3] The symptoms of SARS-CoV-2 infection range from asymptomatic cases through fever and dry cough to serious complications such as pneumonia or acute respiratory distress syndrome.[1,2] The increasing number of people infected with the SARS-CoV-2 posed a burden on health services and a significant public health problem on all continents.[4] In March 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic. Governments worldwide implemented strict measures and lockdowns to prevent the development of the SARS-CoV-2.[5,6] The imposed restrictions, such as travel bans, school closures, limitations on movement, the lack of opportunities to socialize and the shift to remote work for office jobs, have had an impact on limiting physical activity and a rise in sedentary behaviour, including increased screen time.[6–9] It is also worth noting that the COVID-19 pandemic has

Abbreviations: BIA, Bioelectrical Impedance Analysis; BMI, Body Mass Index; COVID-19, Coronavirus Disease 2019; HSD, Honestly Significant Difference; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2; SD, Standard Deviation; WHO, World Health Organization; $\bar{x}$, Arithmetic Mean.

influenced the dietary habits of many individuals. The accompanying stress and anxiety often led to stockpiling of food, especially sweet treats, and increased reliance on ready-made meals and access to fast food.[5,10] This can result in minor fluctuations in body weight, which, in the short term, may solidify into enduring changes and, over the long term, potentially culminate in notable weight increase. Moreover, the closure of schools and gyms could have reduced the availability of organized physical activities and contributed to an energy imbalance due to decreased energy expenditure, which in turn could have promoted the development of excess body mass.[5,7,10] The increasing prevalence of obesity poses a relevant public health problem and is considered a global pandemic. Unfortunately, those with obesity face heightened vulnerability to complications stemming from the SARS-CoV-2, primarily due to the elevated prevalence of chronic conditions that frequently coexist with obesity.[2,4] Beyond its link to an augmented susceptibility to cardiometabolic ailments, obesity's impact is further underscored by the distribution of adipose tissue throughout the body. This condition entails the excessive accumulation of body fat, which in turn engenders a range of health complications, encompassing type 2 diabetes, hypertension and cardiovascular diseases.[4,11,12] Although the body mass index (BMI) is extensively employed for evaluating overweight and obesity, it has certain limitations. The low sensitivity of the method in detecting excess body fat may not fully account for variations in body composition, potentially leading to an underestimation of the risks associated with obesity. Therefore, there are many other methods for assessing body composition, such as dual-energy X-ray absorptiometry, computed tomography, magnetic resonance imaging, the bioelectrical impedance analysis method and anthropometric methods including skinfold and waist circumference measurements.[11,12]

The aim of the study was to assess changes in the distribution of fat tissue and skinfold thickness amongst adolescents aged 11–15 years from Kraków during the COVID-19 pandemic.

2 | METHODS

The research was conducted in two series of cross-sectional studies in 2020 and 2022 in randomly selected primary schools located in four districts of Kraków (Poland): Śródmieście, Nowa Huta, Podgórze and Krowodrza. It is noteworthy that the same schools were involved in both the 2020 and 2022 studies. The study was conducted as recommended by the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Additionally, was approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022). Additionally, permissions were obtained from the principals of the selected schools to commence the research within their institutions. The inclusion criteria for participation in the study were written consent from a parent/legal guardian and verbal consent from the participants themselves.

The study group consisted of adolescents aged 11–15 years, who were divided based on age and sex. The exact calendar age was calculated as the difference between the date of the study and the date of birth, expressed as a decimal fraction. This allowed for the classification of participants into one of five age categories, ranging from 10.50 to 15.49. The study group comprised 1069 individuals in 2020 and 593 individuals in 2022. The distribution of the group by age categories and sex is presented in Table 1.

TABLE 1 Number of children included in the sample.

	2020		2022	
Age category (years)	Girls	Boys	Girls	Boys
11	170	115	94	72
12	107	110	78	79
13	87	115	54	77
14	93	79	44	46
15	100	93	18	31
Total	557	512	288	305
	1069		593	

Body height was measured with an anthropometer (GPM, Switzerland, accuracy – 1 mm) according to Martin's technique. Body weight was obtained using an electronic scale (Tanita, Japan, model BC-418 accuracy – 0.1 kg). BMI was determined according to the formula: body weight/height,[2] where body weight was expressed in kilograms and body height in metres. Additionally, the mean and standard deviation were calculated for measurements of body height, body weight and BMI in individual age categories (Table 2).

The measurement of skinfold thicknesses was performed using a GPM (Switzerland) skinfold calliper with a constant pressure of 10 g/mm^2 (accuracy of 0.5 mm). The measurements included:

- Triceps skinfold: A longitudinal skinfold measured in a standing position, with the arm relaxed, halfway between the acromion and olecranon points, above the triceps muscle.
- Subscapular skinfold: An oblique skinfold measured in a standing position, downwards and laterally from the inferior angle of the scapula.
- Abdominal skinfold: A transverse skinfold measured in a standing position, approximately 5 cm to the side and about 1 cm below the umbilical line.
- Suprailiac skinfold: An oblique skinfold measured in a standing position, above the upper border of the iliac crest.
- Calf skinfold: A longitudinal skinfold measured in a standing position, laterally from the lower edge of the medial condyle of the tibia.

Based on the measured skinfold thicknesses, adiposity indices were calculated:

- The trunk adiposity index: [(subscapular + abdominal +suprailiac)/(triceps + subscapular + suprailiac + abdominal + calf)] × 100

TABLE 2 Mean ($\bar{x}$) and standard deviation (SD) of body height, body weight and BMI in particular age categories.

	Body height (cm)				Body weight (kg)				BMI (kg/m^2)			
	2020		2022		2020		2022		2020		2022	
Age category (years)	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Girls												
11	146.21	7.47	146.85	7.38	38.83	8.96	38.52	7.29	17.98	2.81	17.71	2.41
12	152.88	7.27	154.97	7.22	44.84	8.31	45.05	9.86	19.09	2.74	18.60	2.94
13	158.34	5.61	159.69	5.99	49.18	9.38	49.26	8.32	19.59	3.10	19.26	2.86
14	161.57	7.33	160.68	7.22	55.73	9.04	49.49	12.71	21.10	3.29	19.41	3.23
15	164.17	5.57	164.47	6.81	57.14	11.04	56.31	10.61	21.49	4.08	20.75	3.26
Boys												
11	146.85	7.09	148.15	6.24	40.49	8.92	41.37	9.51	18.64	3.12	18.71	3.37
12	153.56	8.36	153.46	7.57	46.32	10.88	44.39	9.23	19.45	3.39	18.72	2.89
13	159.41	7.50	160.92	8.97	51.36	11.27	51.35	10.80	20.10	3.57	19.72	3.21
14	168.69	8.40	168.68	9.35	57.87	12.12	58.31	13.79	20.22	3.19	20.27	3.63
15	173.49	6.86	171.90	6.88	63.88	13.67	64.68	10.84	21.14	3.89	21.54	2.95

- The limbs-to-total skinfold ratio: [(triceps + calf)/(triceps + subscapular + suprailiac + abdominal + calf)] × 100
- The limbs-to-trunk fat radio: [(triceps + calf)/(subscapular + abdominal)] × 100
- Sum of skinfolds: [triceps + abdominal + subscapular + suprailiac + calf]

Additionally, a description of the socioeconomic situation was provided, utilizing data concerning the birthplaces of parents, their education, occupational status and family structure within the studied cohort. The data comes from surveys filled out by the parents of the surveyed youth in 2020 as part of the 'Child of Krakow 2020' initiative.

Statistical analyses were performed using Statistica 13.3 software. The statistical analysis was conducted to compare the differences between the groups (2020 and 2022) using a two-way analysis of variance ANOVA and Tukey's post-hoc test or the Kruskal–Wallis test. A Shapiro–Wilk test was employed to assess the normality of the distribution of the given feature. Subsequently, the appropriate test was chosen based on the results.

3 | RESULTS

3.1 | Characteristics of socioeconomic conditions of the study group

Predominantly, parents hailed from cities, indicating an urban-centric composition of the studied population. In terms of education, a significant portion of respondents possess at least intermediate education, potentially shaping their educational achievements and career prospects. Parental occupations mainly revolved around intellectual pursuits, potentially influencing the financial stability of households, which constitutes a key dimension of socioeconomic status. Family upbringing primarily occurred within the confines of marriage, potentially affecting the emotional and social well-being of children, thus constituting a crucial element in socioeconomic analysis (Table 3).

3.2 | Girls

In the examined girls, higher values of triceps and calf skinfold thickness were observed across all age categories when analysing the 2022 cohort compared to the girls examined in 2020. A statistically significant difference was found for the triceps skinfold thickness in the group of 11-year-olds (Tables 4 and 5). Additionally, higher values of the suprailiac and the subscapular skinfold thicknesses were noted amongst 11–13-year-olds girls examined in 2022, compared to those examined in 2020 (the difference was statistically significant amongst 11-year-olds) (Tables 4 and 5). However, amongst girls aged 14 and 15, the opposite trend was observed. In the majority of age groups, higher values of abdominal skinfold thickness were observed in girls assessed in 2022 compared to the 2020 cohort (Table 4). Furthermore, girls examined in 2022 exhibited higher values of the sum of skinfolds in the age range of 11–13 (with a statistically significant difference at the age of 11), whilst experiencing a lower value in the same parameter at 14 and 15 years, compared to girls from the 2020 cohort (Table 5). In the examined girls, a lower value of adiposity index of the trunk was noted across all age groups. This highlights that girls from the 2022 cohort presented a lower level of trunk adiposity in proportion to their overall body fat (Table 6). Lower values in the limbs-to-total skinfold ratio were observed across all age categories in the 2022 cohort. However, these differences did not reach statistical significance. Additionally, in the examined girls, a higher limbs-to-trunk fat radio of the trunk was noted across most age groups, except for 13- and 15-year-olds (Table 6). This emphasizes that girls

TABLE 3 Percentage values of the analysed socioeconomic parameters of the parents of the surveyed adolescents.

		Mother's	Father's
Place of birth (%)	Village	10.36	9.85
	City ≤10 000	10.00	11.74
	City ≤100 000	20.00	18.95
	City >100 000	59.64	59.64
Work position (%)	Intellectual work	80.00	69.20
	Physical work	17.54	30.43
	Without an occupation	2.46	0.36
Education (%)	Primary education	0.00	2.55
	Vocational education	5.30	13.87
	Secondary technical	14.13	16.06
	Secondary general education	11.66	8.76
	Higher education	68.90	58.76
Raises a child/legal guardian (%)	Marriage	80.90	
	Single mother	9.38	
	Other	9.72	

TABLE 4 Mean ($\bar{x}$) and standard deviation (SD) of skinfold thicknesses in girls and boys in particular age categories.

Age category (years)	Triceps skinfold (mm)					Subscapular skinfold (mm)					Abdominal skinfold (mm)				
	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020
	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
Girls															
11	8.97	2.71	10.01	2.47	1.04***	10.30	4.55	11.70	4.13	1.40***	12.30	5.48	13.09	5.93	0.79
12	9.08	2.68	10.02	2.51	0.94**	10.79	4.50	12.20	5.13	1.41	12.26	5.32	13.17	5.92	0.91
13	8.98	2.11	9.85	2.49	0.87	10.94	3.71	11.98	4.55	1.04	11.95	4.30	12.31	4.87	0.36
14	9.76	2.84	9.77	3.24	0.01	11.76	4.19	11.58	5.43	−0.18	12.83	4.73	12.59	5.50	−0.24
15	10.36	3.17	10.39	4.68	0.03	12.50	4.76	10.94	4.62	−1.56	12.27	4.68	13.36	5.22	1.09
Boys															
11	10.06	3.27	10.75	3.17	0.69	10.94	5.08	12.94	7.11	2.00	14.27	8.06	15.80	9.87	1.53
12	9.64	3.73	10.25	2.88	0.61	11.42	5.52	11.92	5.39	0.50	14.15	8.20	13.59	7.42	−0.56
13	9.55	4.09	8.87	3.33	−0.68	11.57	6.88	11.33	5.72	−0.24	14.99	9.24	13.88	7.56	−1.11
14	8.08	3.19	8.97	3.83	0.89	9.88	4.55	11.49	5.98	1.61	12.65	6.40	12.91	6.82	0.26
15	7.53	3.57	8.39	3.30	0.86	10.16	5.25	11.11	5.80	0.95	11.65	6.81	12.34	6.69	0.69

$p < 0.01$.*$p < 0.001$.

from the 2022 cohort exhibited lower limb-to-trunk fat ratio values in the extremities in all age groups when compared to girls examined in 2020, as indicated in Table 6.

3.3 | Boys

In boys, at the age of 11–12 and 14–15, higher values of the sum of skinfolds were observed. However, amongst boys in the 13-year-old group, the tendency was the opposite (Table 5). Additionally, higher values of the suprailiac skinfold thickness were noted across all age categories in the 2022 cohort. However, the differences were not statistically significant (Table 5). Similar to girls, higher values of abdominal skinfold thickness were observed amongst 11- and 14–15-year-old boys (Table 4). Additionally, in most age groups, higher values of the calf skinfold thickness were observed when comparing the results of 2022 with the results of 2020 (Table 5). Also, higher values of triceps and subscapular thickness were observed amongst boys at the age of 11–12 and 14–15 examined in 2022 compared to those from the 2020 cohort (Table 4). The boys examined in 2022, showed higher values of trunk adiposity index in the majority of age groups, compared to the 2020 series. This indicates that boys from 2022 exhibited higher trunk adiposity in relation to the overall body fat ratio (Table 6). Additionally, amongst boys examined in 2022, in most age groups, lower values of the limbs-to-total skinfold ratio and the limbs-to-trunk fat radio, compared to the 2020 series. However,

TABLE 5 Mean ($\bar{x}$) and standard deviation (SD) of skinfold thicknesses in girls and boys in particular age categories.

Age category (years)	Suprailiac skinfold (mm)					Calf skinfold (mm)					Sum of skinfolds (mm)				
	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020
	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
Girls															
11	11.53	4.81	12.70	5.19	1.17*	8.81	2.45	11.46	21.29	2.65	52.01	18.44	58.96	29.97	6.95**
12	12.18	4.85	13.26	6.01	1.08	8.64	2.47	9.23	2.46	0.59	52.95	17.90	57.88	20.10	4.90
13	12.25	4.31	12.31	5.37	0.06	8.79	1.99	8.80	2.22	0.01	52.91	14.49	55.25	17.22	2.34
14	13.28	4.81	12.11	5.22	−1.17	9.01	2.50	9.04	2.40	0.03	56.65	16.95	55.10	20.04	−1.55
15	13.32	4.59	12.92	5.09	−0.40	9.33	2.17	9.44	3.30	0.11	57.77	17.31	57.05	21.78	−0.72
Boys															
11	13.01	7.17	14.48	8.42	1.47	9.69	2.76	10.06	3.21	0.37	57.97	24.65	64.03	29.04	6.06
12	13.24	7.35	13.97	6.73	0.73	9.21	3.14	9.30	3.15	0.09	57.66	26.39	59.04	22.74	1.38
13	13.67	8.01	13.86	7.59	0.19	9.51	2.63	9.01	3.15	−0.50	59.30	29.38	56.95	25.26	−2.35
14	12.11	5.97	13.52	7.49	1.41	8.99	2.50	9.00	3.54	0.01	51.71	20.80	55.89	25.68	4.18
15	11.90	6.92	12.65	7.57	0.75	9.26	2.73	8.34	2.53	−0.92	50.50	23.68	52.82	23.70	2.32

*$p < 0.05$.**$p < 0.01$.

TABLE 6 Mean ($\bar{x}$) and standard deviation (SD) of adiposity indices in girls and boys in particular age categories.

Age category (years)	The trunk adiposity index					The limbs-to-total skinfold ratio					The limbs-to-trunk fat radio				
	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020	2020		2022		2022 vs. 2020
	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
Girls															
11	64.79	4.58	64.29	7.36	−0.50	35.21	4.58	35.71	7.36	0.50	83.72	17.50	84.16	21.67	0.44
12	65.58	4.75	65.36	5.44	−0.22	34.42	4.75	34.64	5.44	0.22	81.59	17.27	82.28	20.00	0.69
13	65.63	4.67	65.23	5.29	−0.40	34.37	4.67	34.77	5.29	0.40	81.71	17.59	81.50	17.92	−0.21
14	66.14	4.92	65.00	4.67	−1.14	33.86	4.92	35.00	4.67	1.14	80.12	17.88	82.39	18.39	2.27
15	65.26	4.17	65.04	3.43	−0.22	34.74	4.17	34.96	3.43	0.22	83.20	15.73	83.02	13.45	−0.18
Boys															
11	63.72	6.53	64.55	8.21	0.83	36.28	6.53	35.45	8.21	−0.83	88.04	24.31	87.30	32.10	−0.74
12	65.42	5.82	64.97	6.70	−0.45	34.58	5.82	35.03	6.70	0.45	82.01	22.17	86.99	27.81	4.98
13	65.62	6.27	67.04	5.68	1.42	34.38	6.27	32.96	5.68	−1.42	81.88	23.44	77.20	18.71	−4.68
14	65.63	5.39	66.58	5.84	0.95	34.37	5.39	33.42	5.84	−0.95	81.91	19.09	79.39	22.00	−2.52
15	65.31	5.04	66.64	6.96	1.33	34.69	5.04	33.36	6.96	−1.33	83.35	19.13	78.83	24.41	−4.52

amongst boys aged 12-year-olds, the opposite tendency was observed in the above indicators (Table 6). The observed difference suggests that boys from the 2022 cohort had lower adiposity limb-to-trunk adiposity and reduced lower-limb obesity in relation to total body fat content.

4 | DISCUSSION

Obesity and overweight constitute an excessive accumulation of body fat, leading to serious health risks such as type 2 diabetes, coronary heart disease, respiratory problems and more. This alarming phenomenon continues to rise, affecting adults and children in both developed and developing countries. From 1975 to 2016, there has been a clear increase in the prevalence of overweight and obesity in the 5–19 age group. From 4% in 1975 to as high as 18% on a global scale.[13–16] Additionally, the lockdown associated with the COVID-19 pandemic has deepened the issue of childhood obesity.[17]

In the context of this situation, this work stands out as one of the few studies conducted to analyse changes in fat tissue distribution and skinfold thickness in adolescents during the COVID-19 pandemic. Although skinfold thickness is not the gold standard, it provides a more precise measurement of fat content than BMI. For adolescents, this method can better detect excess adiposity compared to BMI.

Additionally, skinfold thickness is closely correlated with other nutritional indicators and biochemical parameters. This, in turn, means that this measurement method can provide more information about the nutritional status and overall health of the individuals being studied.[18]

The results of the current research suggest that the several months of isolation due to the COVID-19 pandemic had an impact on the distribution of fat tissue and skinfold thickness amongst 11–15-year-olds from Kraków. Amongst the study group from 2022, higher values of all skinfold thickness were observed in most age groups of both sexes compared to the 2020 series. Additionally, there were higher values of both trunk adiposity and the limbs-to-total skinfold ratio in most age groups of both sexes. However, the opposite trend was noted in the results of the limbs-to-trunk fat radio, as the study group from 2022 displayed lower scores compared to their peers from 2020. The distribution of body fat is a result of genetic factors but can also be modified depending on age, sex dietary habits, and various cultural and socioeconomic aspects of the environment.[19] There is a belief that the COVID-19 pandemic has contributed to increased social isolation, stress, feelings of loneliness and depression. These pandemic-induced factors may be a key influence on changes in lifestyle and could further contribute to deteriorating dietary patterns.[17,20] For this reason, the results of current research may be closely linked to changes in dietary habits, levels of physical activity, stress levels and sleep disturbances that occurred during the period of restrictions imposed by the COVID-19 pandemic, not only in Poland but worldwide.

The changes caused by the coronavirus pandemic were observed in the results of a systematic review and meta-analysis that revealed a reduction in physical activity across 14 countries amongst participants aged 4–93, originating from different parts of the world. This decline affected individuals regardless of age and sex.[21] Additionally, the results of multinational surveillance showed increased consumption of potato chips, red meat and snacks alongside a simultaneous decrease in physical activity.[17] Moreover, a study conducted amongst children and adolescents (a sample of 2426 individuals) in China found that physical activity levels declined during the COVID-19 pandemic (dropping from 540 to 105 min/week).[22] Young people aged 3–16 from Spain also reported a reduction in physical activity, up to 103 min/week.[23]

In the context of changing lifestyles during the COVID-19 pandemic, there has been a general increase in the consumption of homemade food and easier access to fast food and ready-made meals. Studies amongst Italian children and adolescents have shown an increase in the consumption of red meat, potato chips and sweet beverages during the lockdown imposed due to the COVID-19 pandemic.[24] An anonymous online questionnaire conducted amongst teenagers (820 individuals) aged 10–19 from Spain, Italy, Brazil, Colombia and Chile revealed that the isolation caused by the SARS-CoV-2 had an impact on the dietary habits of the respondents. Changes were observed in the consumption of fried food, sweets, legumes, as well as fruits and vegetables.[25] This phenomenon can result in an increased excess energy intake. When combined with insufficient physical activity, it leads to weight gain or increased levels of body fat, which in turn is related to the findings of our own research. Unfortunately, individuals with overweight and obesity have alarmingly worsened their dietary patterns and lifestyle during the quarantine associated with the SARS-CoV-2. Factors such as emotional changes and mood can influence dietary choices, leading towards processed foods and sweets. This phenomenon can ultimately contribute to an increase in body fat mass.[10,17,20,26,27]

Additionally, early evidence suggests that both anxiety symptoms (16%) and depression (28%), as well as self-reported stress (8%), were common psychological reactions to the COVID-19 pandemic and may be associated with sleep disturbances,[9] which in turn further exacerbated the stress and increased food consumption.[28] A systematic review and meta-analysis revealed that the estimated prevalence of sleep disorders during the COVID-19 pandemic worldwide was 40.49%. Amongst children and adolescents, it was 42.47%. Interestingly, publications from 2021 showed a more frequent occurrence of sleep problems than in 2020, indicating that the COVID-19 pandemic continues to have a negative impact on sleep.[29] Moreover, research confirms that stress is a risk factor for obesity and weight gain, and during the pandemic, both children and adults experience significant levels of stress.[30]

This research faces several limitations. Firstly, the extended isolation resulting from the COVID-19 pandemic led to a restricted number of participants from the oldest age group. Secondly, the prolonged interruption in school activities due to the pandemic may have caused discomfort for certain students, particularly those with increased body mass, during anthropometric measurements. This circumstance could have influenced the sample's representativeness concerning the distribution of fat tissue and skinfold thickness amongst adolescents. It is also important to emphasize that the study is based on two separate cross-sectional studies conducted in the same schools before and after COVID-19. This means that individual-level causal conclusions cannot be drawn, limiting our ability to interpret the observed changes.

The results of the study shed light on the profound impact of the COVID-19 pandemic on the health of adolescents in Kraków. The observed higher values in skinfold thickness and trunk adiposity index underscore the influence of lifestyle changes induced by isolation measures, distance learning, reduced physical activity and altered dietary habits. These changes not only highlight the direct effects of the pandemic but also raise concerns about long-term health consequences, particularly in the context of cardiometabolic risk factors.

Unfortunately, the results of current research indicate that several months of isolation and related restrictions caused by the COVID-19 pandemic have significantly influenced the distribution of fat tissue and skinfold thickness of adolescents from the Kraków population. Higher values in the trunk adiposity index and skinfold thickness were observed in most age groups. The observed changes can be attributed to lowered physical activity, changes in lifestyle, and intensifying mental disorders.[3,30–32] Given the unfavourable changes in the distribution of adipose tissue and some skinfold thickness, it seems important to introduce intervention programmes aimed at reversing the observed trend. Also comprehensive prophylactic programme is

warranted to mitigate the repercussions of decreased physical activity and unhealthy dietary behaviours prevalent amongst children and adolescents. In addition, it will also be beneficial to investigate whether the described problems are related to future cardiometabolic risk.

AUTHOR CONTRIBUTIONS

PA, MŻ and ŁK have made substantial contributions to conception and design. PA, MŻ and MŻ contributed to the acquisition of data. PA and MŻ prepared analysis and interpretation of data. PA and MŻ have been involved in drafting the manuscript and revising it critically for important intellectual content. PA, MŻ and ŁK have given final approval for the version to be published.

ACKNOWLEDGEMENTS

This study has been sponsored by the University of Physical Education in Kraków (Grant numbers 189/BS/INB/2018 and 330/BS/INB/2023).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

ORCID

Paulina Artymiak https://orcid.org/0000-0002-7291-0121
Magdalena Żegleń https://orcid.org/0000-0001-6028-8905
Łukasz Kryst https://orcid.org/0000-0001-6938-192X

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How to cite this article: Artymiak P, Żegleń M, Kryst Ł. The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland). *Pediatric Obesity*. 2024;e13160. doi:10.1111/ijpo.13160

Załącznik nr 4.

Publikacja 4

Artymiak P, Żegleń M, Kryst Ł.

The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and SelectedIndicatorsRelated to It AmongAdolescents From the Kraków (Poland) Population.

Am J Hum Biol. 2025, 37(1):e24182. https://doi.org/10.1002/ajhb.24182

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ORIGINAL ARTICLE

The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population

Paulina Artymiak | Magdalena Żegleń | Łukasz Kryst

Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Education, Kraków, Poland

Correspondence: Łukasz Kryst (lkryst@poczta.onet.pl)

Received: 5 July 2024 | **Revised:** 27 September 2024 | **Accepted:** 24 October 2024

Funding: This work was supported by Akademia Wychowania Fizycznego im. Bronisława Czecha w Krakowie (grant number: 189/BS/INB/2018, 330/BS/INB/2023).

Keywords: coronavirus | waist circumference | WHR

ABSTRACT

Objectives: The aim of the study was to assess changes in waist and hip circumference, as well as the waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) indices among adolescents (11–15-year-olds) from the Kraków during the COVID-19 pandemic.

Methods: Cross-sectional studies were conducted in four main districts of the city in the years 2020 and 2022. The study group consisted of 1662 people. Measurements of height, waist circumference, and hip circumference were taken. The collected data were used to calculate the WHR and WHtR indices. Statistical analyses were performed using two-way ANOVA and post hoc Tukey's test, as well as the Kruskal–Wallis test, depending on the normality of distribution.

Results: An increase in hip circumference was observed in most age groups of both sexes. Among 14–15-year-old boys, an increase in waist circumference was observed, while among girls, the majority of cohorts showed the opposite trend. Additionally, in most age groups, a decrease in the values of WHR and WHtR indices was observed in both sexes, except for boys aged 14–15.

Conclusion: The study found that government-imposed restrictions related to the COVID-19 pandemic had an impact on waist circumference, hip circumference, WHR, and WHtR indicators among adolescents aged 11–15 from Kraków. While some results showed regression, suggesting potential factors such as reduced physical activity or increased screen time contributing to deteriorating outcomes. On the other hand, not all results changed, which may be attributed to the absence of modifications in dietary habits or physical activity as government restrictions ceased.

1 | Introduction

The highly contagious SARS-CoV-2 virus, responsible for causing severe acute respiratory syndrome and posing an elevated risk to individuals with comorbidities, has led to the emergence of the global pandemic known as COVID-19 (Füzéki et al. 2021; Chiappetta et al. 2020). In response to the swift propagation of the coronavirus, numerous countries have adopted measures such as school closures, sports facility shutdowns, and constraints on personal mobility. These actions collectively aim to mitigate the potential for COVID-19 infection (Bourdas and Zacharakis 2020; Zenic et al. 2020; Füzéki et al. 2021). In Poland, measures like travel restrictions, facility closures (gyms, pools, parks, etc.), and promoting staying at home were taken to limit the spread of the virus. Social distancing, avoiding gatherings, and protecting vulnerable individuals were also emphasized

(Ministry of Health 2021). Despite the fact that the implemented public health restrictions were necessary to prevent the rapid spread of the coronavirus, they had an impact on behaviors related to body weight, level of physical activity, stress, and improper diet (Zenic et al. 2020; Anderson et al. 2023; Artymiak, Żegleń, and Kryst 2024a). A systematic review shows increases in weight, waist circumference, body mass index (BMI), and increased prevalence of obesity, looking at results before and after the coronavirus pandemic (Anderson et al. 2023). Unfavorable changes were also observed in body fatness and fat distribution (Artymiak, Żegleń, and Kryst 2024b). Unfortunately, overweight and obesity were already recognized as a growing public health problem worldwide before the COVID-19 pandemic (Kobylińska et al. 2022; Artymiak et al. 2023). The media temporarily drew attention to the threat that the coronavirus pandemic could pose among individuals with obesity (Kesztyüs, Lampl, and Kesztyüs 2021).

Several studies have demonstrated that childhood obesity elevates the likelihood of developing adult obesity. In addition, it is associated with a higher risk of premature mortality and morbidity, primarily due to the increased risk of developing cardiovascular disease and type 2 diabetes (Huxley et al. 2010; Cao et al. 2018; Kobylińska et al. 2022; Artymiak et al. 2023).

The aim of the study was to assess changes in the circumference waist and hips, as well as WHR and WHtR indices in adolescents aged 11–15 from Kraków during the COVID-19 pandemic.

2 | Materials and Methods

The research was conducted in two sets of cross-sectional studies in 2020 and 2022 in randomly selected primary schools located in four traditional districts (Podgórze, Krowodrza, Śródmieście, Nowa Huta) of Kraków. The anthropometric data for this study were collected during the winter–spring period (January–May) of 2022 and were compared with the results from the "Child of Krakow 2020" project, which was conducted during the winter–spring period (January–March) of 2020, right before the onset of the Covid-19 pandemic. The cross-sectional study was carried out in the same schools. The study group consisted of 1662 individuals (1069 individuals in 2020 and 593 individuals in 2022) (Table 1), aged 11–15 years. All procedures utilized in this study adhered to the ethical standards set by the relevant national and institutional committees on human experimentation and were in accordance with the Helsinki Declaration of 1975, as revised in 2008. Additionally, the study was approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022). Written consent was also obtained from the school principals and the parents/legal guardians of the participants. Moreover, verbal consent was obtained from the participants themselves.

TABLE 1 | Number of children included in the sample.

	2020		2022	
Age category (years)	**Girls**	**Boys**	**Girls**	**Boys**
11	170	115	94	72
12	107	110	78	79
13	87	115	54	77
14	93	79	44	46
15	100	93	18	31
Total	557	512	288	305
	1069		593	

The calendar age of the participants was calculated as the difference between the date of the study and the date of birth, expressed as a decimal fraction. The precise calendar age allowed each participant to be classified into one of five age categories (e.g., individuals whose age fell within the range of 10.50–11.49 were classified as 11-year-olds). Additionally, the examined adolescents were divided by sex.

The height was measured using an anthropometer (GPM; Zurich, Switzerland, accuracy of 1 mm) according to Martin's technique. Additionally, the mean and standard deviation values were calculated for measurements of body height in individual age categories (Table 2). The waist circumference and hip circumference were measured using a nonelastic anthropometric tape with an accuracy of 5 mm.

WHR was calculated using the equation [waist circumference (cm)/hip circumference (cm)] and WHtR [waist circumference (cm)/height (cm)].

Statistical analysis encompassed the comparison of disparities between the 2020 and 2022 groups, accomplished through two-way ANOVA and either Tukey's post hoc test or the Kruskal–Wallis test, contingent upon the distribution's normality. A Shapiro–Wilk test was applied to evaluate the distribution's normality, after which the selection of the suitable test was predicated upon the outcomes. The software utilized for these analyses was Statistica 13.3.

3 | Results

3.1 | Girls

Among girls in the majority of age groups, an increase in hip circumference was observed (the result was significant for 13-year-olds). In the case of waist circumference, in most age groups, lower values were observed among girls tested in 2022 compared to girls in 2020. However, among 15-year-olds, an increase in the analyzed measurement was noted when comparing girls examined in 2022 with peers from the 2020 series. The differences were not statistically significant (Table 3). Additionally, among girls from the 2022 series, compared to those surveyed in 2020, lower values of the waist circumference values in relation to hip circumference were observed, with statistically significant differences in the age range of 11–14. However, among 15-year-old girls, the trend was reversed. Furthermore, among the study group in 2022, lower values of the waist circumference values in relation to height were observed compared to the 2020 series. The differences were statistically significant at the age of 11, 12, and 14 (Table 4).

TABLE 2 | Mean ($\bar{x}$) and standard deviation (SD) of body height in particular age categories.

	Body height (cm)				
	2020		2022		
Age category (years)	$\bar{x}$	SD	$\bar{x}$	SD	2022 vs. 2020
		Girls			
11	146.21	7.47	146.85	7.38	0.64
12	152.88	7.27	154.97	7.22	2.09
13	158.34	5.61	159.69	5.99	1.35
14	161.57	7.33	160.68	7.22	−0.89
15	164.17	5.57	164.47	6.81	0.30
		Boys			
11	146.85	7.09	148.15	6.24	1.3
12	153.56	8.36	153.46	7.57	−0.1
13	159.41	7.50	160.92	8.97	1.51
14	168.69	8.40	168.68	9.35	−0.01
15	173.49	6.86	171.90	6.88	−1.59

TABLE 3 | Mean values ($\bar{x}$) and standard deviation (SD) of the analyzed parameters and their differences between the studies from 2020 and 2022 within age categories.

	Waist circumference (cm)					Hip circumference (cm)				
	2020		2022			2020		2022		
Age category (years)	$\bar{x}$	SD	$\bar{x}$	SD	2022 versus 2020	$\bar{x}$	SD	$\bar{x}$	SD	2022 versus 2020
					Girls					
11	62.83	7.07	59.95	5.91	−2.88**	76.31	6.99	77.30	6.34	0.99
12	64.76	6.62	62.78	7.52	−1.98*	81.08	6.93	82.64	7.73	1.56
13	66.19	6.57	65.42	6.86	−0.77	84.32	7.04	86.03	7.08	1.71*
14	68.61	7.16	64.94	7.35	−3.67**	88.38	7.38	86.99	7.83	−1.39
15	68.53	9.31	69.14	8.39	0.61	91.32	7.55	90.28	6.83	−1.04
					Boys					
11	66.58	8.05	65.10	9.17	−1.48	77.83	7.57	78.74	7.67	0.91
12	67.68	10.91	66.04	7.52	−1.64	81.61	8.68	80.83	7.10	−0.78
13	71.43	9.01	71.08	8.80	−0.35	85.28	8.63	85.42	7.66	0.14
14	71.11	12.03	73.72	10.21	2.61	87.89	8.11	89.17	9.04	1.28
15	74.70	9.73	77.03	8.53	2.33*	91.58	8.99	89.95	18.37	−1.63

*$p < 0.05$.
**$p < 0.001$.

3.2 | Boys

Among boys examined in the year 2022, there was an increase in hip circumference values among those aged 11, 13–14, when compared to their counterparts from the 2020 cohort. While lower values were observed among 12 and 15-year-olds. However, these differences were not statistically significant. Additionally, a decrease in the values of the waist circumference was observed in the age groups of 11–13-year-olds, while an increase was noted in 14–15-year-olds. These differences were statistically significant among 15-year-old boys (Table 3). Similar trends were observed for the WHR and WHtR. Boys

TABLE 4 | Mean values and standard deviation of the analyzed parameters and their differences between the studies from 2020 and 2022 within the age category.

	WHR					WHtR				
	2020		2022		2022 versus	2020		2022		2022 versus
Age category (years)	$\bar{x}$	SD	$\bar{x}$	SD	2020	$\bar{x}$	SD	$\bar{x}$	SD	2020
					Girls					
11	0.82	0.05	0.78	0.04	−0.04***	0.43	0.04	0.41	0.04	−0.02***
12	0.80	0.04	0.76	0.05	−0.04***	0.42	0.04	0.40	0.04	−0.02***
13	0.79	0.04	0.76	0.04	−0.03***	0.42	0.04	0.41	0.04	−0.01
14	0.78	0.06	0.75	0.04	−0.03***	0.43	0.05	0.40	0.04	−0.03**
15	0.75	0.06	0.77	0.06	0.02	0.42	0.06	0.42	0.05	0.00
					Boys					
11	0.85	0.05	0.83	0.06	−0.02***	0.45	0.05	0.44	0.06	−0.01**
12	0.83	0.09	0.82	0.05	−0.01**	0.44	0.07	0.43	0.04	−0.01
13	0.84	0.05	0.83	0.06	−0.01	0.45	0.05	0.44	0.06	−0.01
14	0.81	0.12	0.83	0.06	0.02	0.42	0.07	0.44	0.05	0.02
15	0.81	0.05	0.82	0.04	0.01	0.43	0.05	0.44	0.04	0.01*

Abbreviations: WHR, waist to hip ratio; WHtR, waist to height ratio.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

from the 2022 cohort exhibited lower values of the waist circumference values in relation to hip circumference, in the age range of 11–13 years (statistically significant for WHR at ages 11–12). Concurrently, there was an increase in the waist circumference values in relation to hip circumference values among 14-year-olds and 15-year-olds. Among the boys examined in 2022, lower values of the waist circumference values in relation to height were observed at the age of 11–13, while the reverse trend was noted in 14 and 15-year-olds, compared to the 2020 series (statistically significant differences in the age of 11 and 15) (Table 4).

4 | Discussion

The increasing prevalence of overweight and obesity among children and adolescents worldwide is a subject of serious concern due to its significant implications for both health and the economy (Bacopoulou et al. 2015; Cameron et al. 2020). Obesity is a common condition, the prevalence of which is constantly increasing, often with long-term consequences such as type 2 diabetes and cardiovascular diseases, but also with negative impacts on social and emotional health (Lurbe, Alvarez, and Redon 2001; Cardel et al. 2020). As the epicenter of the COVID-19 pandemic shifted from the Asian region to the European continent and then to North and South America, the impact of obesity on the course of COVID-19 gained significance. Both of these continents were characterized by some of the highest obesity rates in the world. Additionally, overall obesity is associated with a more severe course of the SARS-CoV-2 (Petersen et al. 2020).

Research has been conducted in this aspect to analyze changes in waist and hip circumferences, as well as the WHR and WHtR indicators among adolescents in the Kraków population during the COVID-19 pandemic. While comprehensive information on optimal methods for determining excess body weight was lacking, common approaches to assessing nutritional status and fat tissue accumulation include measurements of body height, weight, waist, and hip circumferences. Additionally, indicators such as WHR, WHtR, and skinfold thickness offered a more detailed description of fat distribution compared to BMI. From a public health point of view, the methods described may better detect excess body fat in adolescents, which is closely linked to lifestyle and dietary habits, as well as a reflection of central obesity in the younger generation (Cameron et al. 2020; Leslie 2020; Watanabe et al. 2022; Zhang et al. 2021).

The results of the current research suggest that government restrictions imposed due to the coronavirus pandemic, such as the closure of schools, remote learning, limitations on social gatherings, and the closure of service establishments (including gyms and swimming pools), have had an impact on the performance of Kraków's adolescents. For both sexes, an increase in hip circumference values was observed in the majority of age groups. Additionally, among boys, there was an observed increase in waist circumference values and the WHR and WHtR indicators at the ages of 14 and 15. The current research also revealed a decrease in waist circumference results among girls in the majority of age groups. Furthermore, among girls, a decline in the values of the WHR and WHtR indicators was observed in most age groups. Also, among boys, a decrease in the values of the WHR and WHtR indicators was observed at the ages of 11–13.

Similar results were observed among the Spanish children and adolescents aged 6–18, as they showed an increase in hip circumference values in the majority of age categories for both sexes during the COVID-19 pandemic. In contrast to the current findings, the analysis of Spanish data revealed an increase in waist circumference, waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) in the majority of age groups. In the current results, an increase in these parameters was observed only in the oldest cohorts (Rúa-Alonso et al. 2022). A similar trend could also be observed among adult Chinese individuals, as there was an increase in body weight, waist circumference, hip circumference, and indicators such as BMI, WHR, and WHtR (He et al. 2022).

The observed changes may result from the anatomical distribution of body fat, a trait influenced by genetic factors. However, these features can undergo modifications depending on factors such as sex, age, dietary habits, and socioeconomic aspects (Lurbe, Alvarez, and Redon 2001; Kaur and Talwar 2011). Therefore, it was suggested that government restrictions due to the COVID-19 pandemic have adversely affected lifestyle, including dietary habits, physical activity, screen time, sleep quality, and social determinants of health among adolescents, which may be associated with the current research findings (Bates et al. 2020; Galluccio et al. 2021; Rúa-Alonso et al. 2022; Yilmaz and Karadag 2022; Anderson et al. 2023).

Research shows that 81% of European students did not meet the physical activity guidelines during the coronavirus pandemic (Kovacs et al. 2022). Additionally, in the results of a study among Canadian children (5–11 years old) and adolescents (12–17 years old), it was observed that only 4.8% of children and 0.6% of adolescents met the guidelines for physical activity during the lockdown caused by the COVID-19 pandemic (Moore et al. 2020). Adequate levels of physical activity promote many health benefits and have an impact on the cardio-metabolic system, motor development, emotional regulation, mood, and maintaining a healthy body weight in children and adolescents (Janssen and Leblanc 2010; Galluccio et al. 2021; Neville et al. 2022).

Moreover, the correlation between a decrease in physical activity and excessive screen exposure, as well as a sedentary lifestyle, is particularly evident in the case of children and adolescents. Furthermore, increased screen time is associated with mental health risks and is linked to cardiometabolic risk factors such as obesity, hypertension, etc. (Nagata et al. 2022; Musa, Elyamani, and Dergaa 2022). Notably, these observations may find relevance in current research, where we evidenced an increase in hip circumference among both sexes. The SARS-CoV-2 pandemic has led to an increase in sedentary behavior and screen time worldwide. Common factors associated with the increase in sedentary lifestyle include a lack of physical space, motivation, interest in physical activity, or a lack of knowledge about exercise (Martins et al. 2021). The results of an observational study ($n = 8395$) conducted in 10 European countries indicate that children and adolescents aged 6–18 exceeded the daily screen time limit. Specifically, the exceedance was noted at 69.5% on weekdays and 63.8% on weekends (Kovacs et al. 2022). Additionally, the results of the Adolescent Brain Cognitive Development study conducted among teenagers in the USA show that screen time averaged 7.70 h per day during the COVID-19 pandemic, compared to 3.8 h per day before the pandemic (Nagata et al. 2022).

The isolation resulting from the COVID-19 pandemic has had an impact on changes in the lifestyle of the younger generation. The closure of educational institutions and the transition to remote learning have affected not only physical activity and screen time but also sleep quality. These changes are significant, especially in the context of mental health and the overall well-being of young people. Sleep disturbances have become one of the clear consequences of this new way of life. Continuous hours in front of a screen can lead to difficulties falling asleep and worsen sleep quality. This, in turn, can negatively affect concentration, emotional health, immune system function, and academic performance. It is recommended that children and adolescents aged 5–17 sleep from 9 to 11 h per day, but many of them struggle to achieve this standard. The implementation of online learning and the lack of regular school hours have led to a change in the sleep patterns of many young individuals (Bates et al. 2020; Moore et al. 2020; Galluccio et al. 2021). Additionally, the younger generation is shifting their bedtime to a later hour, which further negatively affects sleep quality, increases stress, and promotes increased food consumption (Bates et al. 2020), potentially leading to weight gain.

On the other hand, not all results of the current research have worsened. Analyses indicate that the lockdown caused by the coronavirus pandemic has contributed to positive changes in some dietary habits and physical activity. An example of this is the observed increase in the consumption of raw vegetables, whole grains, and fresh food, likely stemming from the extended free time for meal preparation (Lombardo et al. 2021). Furthermore, survey studies evaluating self-assessment of lifestyle in 15–17-year-olds showed that both girls and boys declared maintaining an active lifestyle and consistency in dietary habits (Galluccio et al. 2021). It is worth noting that research conducted among adolescents and medical students in Croatia did not reveal significant changes in dietary habits when comparing the period before and during the pandemic caused by the SARS-CoV-2 virus. However, changes were observed in the dietary pattern regarding the recommendations of the food pyramid, especially in the consumption of fruits, legumes, fish, and sweets (Dragun et al. 2020).

This study faces several limitations. First, the extended period of isolation due to the COVID-19 pandemic resulted in a lower participation rate among adolescents in the oldest age group. Additionally, the interruption of school activities during the pandemic might have caused some discomfort for students with higher body mass during anthropometric measurements, potentially impacting the representativeness of the sample with respect to BMI. However, this study is distinguished by several unique aspects. Firstly, it provides significant insights into the physical consequences of the pandemic, such as the increase in sedentary behavior, changes in dietary habits, and the reduction in physical activity among adolescents. Additionally, the examination of differences in the pandemic's impact on boys versus girls and across various age groups offers valuable data, highlighting the need for health interventions to be tailored to the specific needs of different demographic groups. Furthermore, the longitudinal nature of this study allows for a detailed

comparison, revealing how the pandemic has influenced trends in physical health over time.

In summary, in the analyzed cohort, it was observed that the restrictions imposed by the government in connection with the COVID-19 pandemic had an impact on waist circumference, hip circumference, and the WHR and WHtR indicators among adolescents aged 11–15 from the Krakow population. However, not all results showed regression. Deteriorating results in the current studies may be caused by a decrease in physical activity, an increase in screen time, or poor sleep quality, which, in turn, may correlate with a worsening emotional state, promoting excessive food consumption. On the other hand, not all results changed, which could be supported by the lack of changes in dietary habits or online and outdoor physical activity with the easing of government restrictions. In future research, it is valuable to investigate whether the restrictions implemented during the COVID-19 pandemic will have a long-term, negative impact on waist and hip circumference, as well as selected indicators among the youth. Additionally, consideration could be given to the development of targeted interventions aimed at maintaining a healthy lifestyle and preventing unhealthy physical activity and dietary habits among the younger population.

Author Contributions

P.A. and Ł.K. have made substantial contributions to conception and design. P.A., M.Ż., and Ł.K. contributed to the acquisition of data. P.A. prepared analysis and interpretation of data. P.A. and M.Ż. have been involved in drafting the manuscript and revising it critically for important intellectual content. P.A., M.Ż., and Ł.K. have given final approval for the version to be published.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Research data are not shared. The data are not publicly available due to privacy or ethical restriction.

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Załącznik nr 5.

Publikacja 5

Artymiak P, Żegleń M, Kryst Ł.

Changes in body composition (muscle mass and adiposetissue) among adolescents aged 11–15 from Kraków during the COVID-19 pandemic.

Anthropol Rev. 2025, *87*(4), 55–67.

https://doi.org/10.18778/1898-6773.87.4.04

Anthropological Review • Vol. 87(4), 55–67 (2024)

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.18778/1898-6773.87.4.04

Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11–15 from Kraków during the COVID-19 pandemic

Paulina Artymiak, Magdalena Żegleń, Łukasz Kryst

Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Culture, Kraków, Poland

Abstract: Study aim: To assess changes in body composition, specifically focusing on muscle mass and adipose tissue, among adolescents aged 11–15 in Kraków during the COVID-19 pandemic.

Materials and Methods: Cross-sectional studies were conducted in four selected districts of the city of Kraków in the years 2020 and 2022 (before and after the COVID-19 pandemic). The study group included adolescents aged 11–15 years. The percentage of body fat (%BF) was measured using the bioimpedance method. Additionally, measurements of height, arm circumference, and skinfold thickness of triceps were taken using a skinfold calliper. The collected data were used to calculate the Corrected Arm Muscle Area (CAMA). The normality of the distribution of each feature was assessed using the Shapiro-Wilk test. Statistical analysis was performed to compare differences between groups using two-way ANOVA with Tukey's HSD post-hoc test or the Kruskal-Wallis test.

Results: Among girls, a decrease in muscle mass was observed in most age categories. The opposite trend was observed among boys, as an increase in muscle mass was observed in most of the age groups. Girls were characterized by a decrease in the %BF in all cohorts, while in boys, an increase in the %BF was observed among 11,13 and 15-year-olds. In most age groups, there was an increase in the average muscle mass and increase in the %BF depending on BMI (Body Mass Index) categories in both sexes.

Conclusions: This study found no notable variances in muscle mass and %BF within the examined group amid the COVID-19 pandemic. While certain outcomes indicated regression, possibly linked to reduced physical activity or prolonged sedentary periods, not all research findings exhibited decline. This could be attributed to online physical activity or enhanced dietary habits.

Key words: coronavirus, children, muscle mass, body fat

Received: 23.04.2024; Revised: 3.09.2024; Accepted: 5.12.2024

Introduction

The disease caused by the SARS-CoV-2, has been recognized as one of the most serious pandemics in the world, significantly impacting the lifestyles of billions of children and young people (Karatzi et al. 2021; de Girolamo et al. 2022; Kutac et al. 2022; Musa et al. 2022). To prevent the spread of the coronavirus and the collapse of national healthcare systems, governments on all continents have imposed strict isolation measures on their citizens. The implemented precautionary measures included the closure of schools for a significant portion of 2020 at all levels of education, restrictions on travel and various forms of transportation, the closure of shops, restaurants, and all non-essential businesses where remote work was feasible, and the government mandated stay-at-home orders (Martinez-Ferren 2020; Damanti et al. 2021; Karatzi 2021; Musa et al. 2022). Unfortunately, some of the imposed restrictions, such as social distancing, closure of gyms and sports facilities, as well as limitations on outdoor activities have significantly impacted people's lifestyles, including overall health status, habits related to physical activity, diet, and other health-related behaviors (Lesser, Nienhuis 2020; Tison et al. 2020). Research has shown that during the pandemic unhealthy eating patterns have risen, including changes in the types of food consumed as well as changes in other eating habits that might have caused the loss of control over the caloric content of consumed food (Ammar et al. 2020). It has been suggested that the current lack of physical activity may lead to the formation of entrenched habits that persist after the SARS-CoV-2 crisis (Chen et al. 2020). The factors described above can also contribute to the occurrence of overweight, obesity, and a decline in physical fitness (Kovacs et al. 2021; Kutac et al. 2022). This is supported by the findings of an online survey conducted in Italy, showing that 49.6% of respondents did not change their diet, 46.1% of respondents reported eating more during the lockdown, and 19.5% gained weight. The survey revealed a notable increase in the consumption of "comfort food," particularly ice cream, chocolate, desserts (42.5%), as well as salty snacks (23.5%). Despite reduced access, 21.2% of participants increased their intake of fresh vegetables and fruits (Scarmozzino, Visioli; 2020). In turn, obesity was shown to be a significant public health issue that increases the risk of cardiometabolic problems such as cardiovascular diseases, diabetes, hypertension, and dyslipidemia, and it is correlated with an increased risk of COVID-19 complications (Krams et al. 2020; WOF 2020; Karatzi et al. 2021; Loza et al. 2022). Body composition analysis is one of the methods of assessing health status, nutritional status, and the impact of illness and dietary changes (Toomey et al. 2015; Kutac et al. 2022). Body composition measurement provides insights into the health status and lifestyle habits of young individuals. Body composition is influenced by genetic and exogenous factors, physical activity, nutrition, and overall health (Kutac et al. 2022). Studies among adolescents aged 11–18 have shown that the COVID-19 pandemic has significantly affected body composition. For example, there has been an increase in adipose tissue surface area and visceral adipose tissue, accompanied by a decrease in skeletal muscle mass. In addition, no significant changes in body weight and Body Mass Index (BMI) have been observed (Kutac et al. 2022).

Studies have shown that the pandemic may have contributed to an increase in the rate of weight gain among children and adolescents due to limited access to physical activity and extracurricular activities (Kovacs et al. 2021; Loza et al. 2022). Data collected worldwide have documented a significant decrease in physical activity, coupled with an increase in screen time during the SARS-CoV-2 virus-induced pandemic (Kovacs et al. 2021). Research on Austrian children aged 7–10 further highlights these trends, revealing a decline in cardiovascular-respiratory fitness alongside increases in BMI SDS values. The prevalence of overweight and obesity among these children rose from 15.0% to 21.2% when analysing the results before and after the COVID-19 pandemic (Jarnig et al. 2022). These data are supported by observational studies (n=8395) conducted in 10 European countries, which reported the exceeding of the daily screen time limit (>2 hours/day) among 69.5% of young individuals aged 6–18 during weekdays and 63.8% on weekends (Kovacs et al. 2021). Furthermore, among adolescents in Shanghai, an increase from 21.3% to 65.6% in physically inactive students was recorded (Xiang et al. 2020).

The aim of the study was to assess changes in body composition, specifically the proportion of muscle mass and adipose tissue, among adolescents aged 11–15 from Kraków during the COVID-19 pandemic.

Materials and methods

The adolescents analysed in this study were included in two series of cross-sectional studies conducted in 2020 and 2022, carried out in randomly selected primary schools located in four traditional districts (Śródmieście, Podgórze, Krowodrza, Nowa Huta) of Kraków.

The study group consisted of adolescents aged 11–15, who were divided by age and sex. The calendar age of the participants was calculated as the difference between the date of the study and the date of birth, expressed as a decimal fraction. The calendar age of the participants ranged from 10.50 to 15.49 years and served as the basis for classifying each participant into one of five age groups (e.g., adolescents aged 10.50–11.49 years were classified as 11-year-olds). The sample size included 1069 individuals in 2020 (557 girls, 512 boys) and 593 children in 2022 (288 girls, 305 boys) (Tab. 1).

Table 1. Number of children included the sample

Age category [yrs.]	2020		2022	
	Girls	Boys	Girls	Boys
11	170	115	94	72
12	107	110	78	79
13	87	115	54	77
14	93	79	44	46
15	100	93	18	31
Total	557	512	288	305
	1069		593	

The data from the 2022 survey series was compared with the results from the series in 2020. The study was conducted as recommended by the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008 and was approved by the Bioethics Committee of the Regional Medical Association in Kraków (5/KBL/OIL/2019, 66/KBL/OIL/2022). In addition, the study was conducted with the consent of school principals. The basis for the inclusion of the participant in the study was the written consent of the parent/legal guardian, as well as the oral consent of the subjects themselves before the study begin. Possible exclusion from participation was based on the lack of consent of the parent/legal guardian, participant or information about contraindications to the study.

In both studies, researchers have followed COVID-19 standard operating procedures.

All anthropometric measurements took place in the morning hours. The youth were dressed in gym clothes and were barefoot. The anthropometric data obtained in this study covered the winter-spring period (January–May) in 2022, which were analysed comparatively with the results of the "Child of Krakow 2020" project, conducted in the winter-spring period (January–March) in 2020, just before the year in which the COVID-19 pandemic began. Both studies collected data from the same schools.

Body height was measured using an anthropometer (GPM, Switzerland, with an accuracy of 1mm) according to Martin's technique. To measurement of the percentage of adipose tissue was conducted using the portable segmental body composition analyser (bioimpedance method BIA; Tanita, Japan, with an accuracy of 0.1%). The study was conducted according to a standard protocol for all participants. The measurements were taken in the morning hours, under similar temperature and humidity conditions.

A non-stretch anthropometric (with an accuracy of 5mm) tape was used to measure the circumference of the arm (cm). The arm circumference was measured at the midpoint of the humerus bone. The measurement of the triceps brachii skinfold (in mm) was taken at the midpoint of the arm, on the right side of the body, using a skinfold calliper (a constant pressure of 10g/mm^2 and an accuracy of 0.5mm). Both measurements were used to calculate the corrected arm muscle area (CAMA). Total body muscle mass (kg) was calculated from CAMA using a prediction equation:

Formula for women:

$$CAMA = [(MAC-(\pi \times TSF))^2/4\pi]-6,5$$

Formula for men:

$$CAMA = [(MAC-(\pi \times TSF))^2/4\pi]-10$$

TSF denotes triceps skinfold and MAC mid-arm circumference (cm) while the term 6.5 refers to the correction for bone area in females and 10 for men.

$$\text{Muscle mass (kg)} = H \times (0.0264+(0.0029 \times CAMA))$$

H- body height (cm)

Statistical analysis was performed using the Statistica software (version 13.3). To compare the differences between the 2020 and 2022 cohorts, two-way ANOVA and Kruskal-Wallis test were performed. According to the assumptions, the observable effect should reflect both waves of the pandemic.

Results

Girls

A decrease in muscle mass was observed among the examined girls in the majority of age groups, analysing the cohort from 2022 compared to peers examined in 2020 (the difference was statistically significant among 14-year-olds). However, among 11- and 12-year-old girls the opposite trend was observed, as muscle mass increased (Tab. 2).

Table 2. Mean and SD values of muscle mass and body fat in particular age categories and differences between cohorts

Age category [years]	Muscle mass [kg]					BF [%]				
	2020		2022		2022 vs 2020	2020		2022		2022 vs 2020
	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
Girls										
11	14.50	3.76	14.72	3.67	0.22	19.96	6.35	19.45	6.26	-0.51
12	16.82	3.78	17.02	4.82	0.20	21.40	6.60	20.91	6.69	-0.49
13	18.11	3.83	17.62	3.51	-0.49	21.79	5.96	21.45	5.94	-0.34
14	21.03	4.40	18.55	4.75	-2.48**	24.11	6.53	21.00	6.52	-3.11**
15	21.60	4.57	20.49	3.83	-1.11	24.27	7.44	23.19	6.07	-1.08
Boys										
11	14.97	3.68	15.93	4.87	0.96	16.88	6.63	18.07	7.03	1.19
12	17.91	5.05	17.37	4.74	-0.54	16.48	6.91	16.36	5.85	-0.12
13	20.09	4.66	19.84	5.28	-0.25	14.90	7.03	14.94	6.49	0.04
14	22.68	6.20	23.74	5.94	1.06	13.27	6.07	12.75	5.07	-0.52
15	27.11	6.57	27.50	6.47	0.39	13.01	6.75	14.24	5.46	1.23

**- statistically significant $p<0.01$

Furthermore, the analysis of the %BF in girls examined in 2022 compared to 2020 showed a general decrease in all age categories. There was a statistically significant difference among 14-year-olds (Tab. 2).

Figure 1 illustrates the average percentage of body fat according to BMI categories. Among girls, an increase in the occurrence of both underweight and overweight was observed. In addition, an increase in the average values for all BMI categories was observed. However, an opposite trend was observed in the case of normal body weight (Fig. 1).

Analogous values were observed when analysing the results of average muscle mass in the context of BMI categories (Fig. 2).

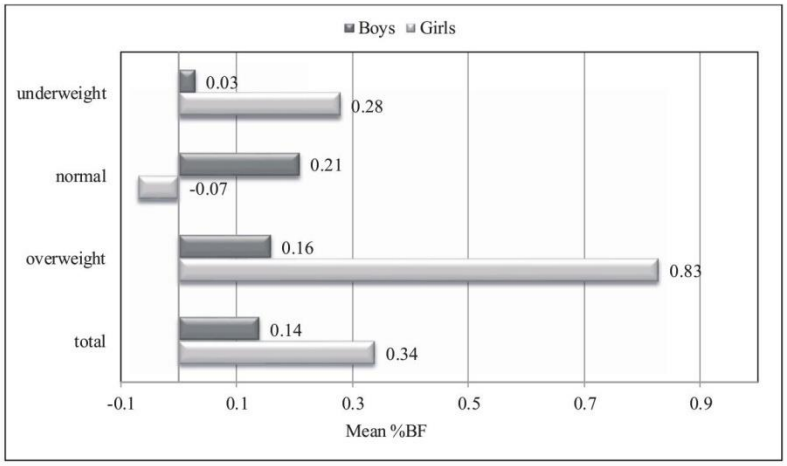

Figure 1. Mean ($\bar{x}$) of % Body Fat for the Total (girls and boys)

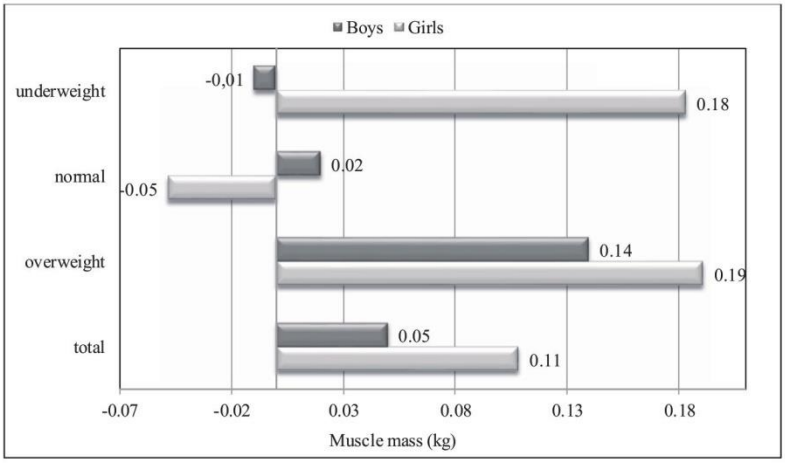

Figure 2. Mean ($\bar{x}$) of muscle mass for the Total (girls and boys)

Boys

In boys aged 11, 13, and 15, an increase in muscle mass was observed, analysing the results from 2022 compared to boys examined in 2020. Among the other groups (12 and 14 years), a decrease in muscle mass was observed but without significant differences (Tab. 2). In addition, an increase in %BF was observed in most age groups, except for 12 and 14-year-old boys who exhibited a decreasing pattern (Tab. 2). There was an increase in all average body fat percentage values in different BMI categories (Fig. 1).

Moreover, Figure 2 depicts the results of the average muscle mass in various BMI

categories. An increase in both normal body weight and overweight was observed. Furthermore, there was an increase in the average values for all BMI categories. Only a different trend was observed in the underweight category (Fig. 2).

Discussion

Body composition

The high prevalence of obesity has reached the dimensions of a pandemic, especially in developed countries in the West. Obesity in children and adolescents poses a significant health threat, and is associated with insulin resistance, risk factors for cardiovascular diseases, type 2 diabetes, cancers, and increased mortality (Trang et al. 2019; Stierman et al. 2021; Brambilla et al. 2022). According to the assessment of the World Health Organization (WHO), obesity, as a non-communicable disease, is a key risk factor for severe illness resulting from the SARS-CoV-2, which was operating as a global pandemic characterized by severe pneumonia and a significant level of mortality and morbidity (Malavazos et al. 2020, WHO 2020). Although government-imposed restrictions, such as social distancing, home isolation, limitations on travel and gatherings were necessary non-pharmaceutical interventions to control the spread of the SARS-CoV-2, they significantly impacted the health and behaviours of society, as well as the daily routines of people worldwide (Wang et al. 2020; Jeong et al. 2023). Remaining inactive has become more accessible than ever before. As a result of these restrictions, there has been a reduction in physical activity, an increase in sedentary time, and changes in dietary habits (Kirwan et al. 2020). According to a study by Rúa-Alonso et al. (2022), the COVID-19 pandemic-induced social restrictions may have had a negative impact on the body composition of children and adolescents, resulting in increased rates of obesity, as well as a reduction in muscle strength. Hence, it is important to monitor body composition among the young population, reflecting their behaviour and potentially impacting their current health status (Hernández-Ortega, Osuna-Padilla 2020). To address these issues, this study was conducted to assess changes in body composition, with particular emphasis on the proportion of muscle mass and adipose tissue, among adolescents aged 11–15 in Kraków during the COVID-19 pandemic. The results of this study suggest that restrictions related to limiting the spread of the SARS-CoV-2 had contributed to changes in muscle mass and %BF among adolescents in Kraków. Among girls, a decrease in muscle mass was observed among most of the age groups. Conversely, boys showed the opposite trend, as an increase in muscle mass was observed in most of the age categories. Girls exhibited a decrease in the percentage of body fat in all age categories, whereas boys showed an increase in the percentage of body fat in most of the age groups. In addition, an increase in the average muscle mass was observed in most the age groups, depending on the BMI category in both sexes. Furthermore, an increase in body fat was observed in both girls and boys across all BMI categories.

Physical activity

Similar results were observed in young basketball players, as during the quarantine period caused by the SARS-CoV-2 virus, higher values of body fat and lower percentages of total muscle mass were noted. In addition, a lower level of

explosive strength in the lower limbs was observed among the subjects, which was accompanied by lower aerobic endurance. One study suggests that the interruption of the training process and a decrease in physical activity due to the restrictions imposed during the coronavirus pandemic had a negative impact on the condition of young basketball players (Pelemiš et al. 2023). A study conducted in the Kraków population also showed that the level of physical fitness in children during the pandemic worsened markedly (Artymiak et al. 2024). For proper functioning and maintenance of muscle mass during the developmental period, it is crucial to achieve the level of daily physical activity recommended by the WHO, which is at least 60 minutes of moderate- or vigorous-intensity activity per day, covering the age group from 5 to 17 years. Unfortunately, over 80% of teenagers worldwide are not sufficiently active physically (Kutac et al. 2020; Mondaca et al. 2023; WHO 2022). A survey-based study conducted internationally with participants primarily from Asia, Africa, and Europe reported that, amidst the lockdown imposed by the coronavirus pandemic, there was a 33.5% reduction in the amount of time dedicated to daily physical activity. In addition, the study reported an uptick in sedentary behaviour, amounting to an increase of 3 hours per day (Ammar et al. 2020). Similar studies were conducted among children and adolescents aged 6–18 living in Italy showing a decrease in sports physical activity by 2.3 hours per day. Furthermore, an extension of sedentary time and screen time by 4.85 hours/day was observed (Kirwan et al. 2020). These results correspond to findings of this study, as a decrease in physical activity was observed, which may be associated with a reduction in muscle mass among surveyed girls in all age categories. It could be suggested that the introduced isolation measures due to the SARS-CoV-2 contributed to a decrease in physical activity, which may be associated with an increase in sedentary lifestyle and screen time.

Dietary habits

Longer time spent in front of the screen may adversely affect the younger generation, both in terms of sleep quality and the loss of muscle mass associated with stress and sleep restriction (Kirwan et al. 2020; Ito et al. 2022). Recommendations regarding 24-hour movement suggest limiting screen time to less than two hours per day and ensuring an adequate amount of sleep, depending on the age group. Studies on Swedish youth indicated that after the pandemic, the time dedicated to sleep has shortened, while screen time has lengthened (Helgadóttiret al. 2023). Shortened sleep duration may also affect appetite and eating habits, increasing the consumption of snacks, fast foods, and sugary drinks (Morselli et al. 2010; Chang et al. 2021). This, in turn, could lead to unfavourable changes in the relationship between calories consumed and expended, influencing fat storage and BMI increase. It is worth noting that youth showing normal body fat content typically exhibits better dietary patterns compared to their overweight and obese peer. Childhood and early adolescence are crucial for developing physical skills that form the foundation of a healthy lifestyle throughout life (Maltoni et al. 2021; Kutac et al. 2022; Syukrina et al. 2023). Moreover, a study conducted in Italy using online questionnaires showed an improvement in eating habits exhibited by a higher consumption of fruits, vegetables, and legumes during

the isolation caused by the coronavirus pandemic (Grant et al. 2021). Similarly, cross-sectional studies involving the adult population in Spain revealed a positive impact of isolation caused by SARS-CoV-2 on dietary habits and physical activity (López-Bueno et al. 2020).

This study has several limitations. Firstly, due to the prolonged isolation caused by the COVID-19 pandemic, a limited number of students from the oldest age group consented to participate in the study. Secondly, the long period of break in school activities caused by the pandemic could have caused discomfort for some students with higher body mass during anthropometric measurements. This phenomenon could have affected the representativeness of the sample in the context of body composition.

In this cross-sectional study, minor changes in muscle mass and body %BF among the examined population during the COVID-19 pandemic. The results of this study may reflect changes in physical activity or increased time spent in a sitting position. On the other hand, not all results showed a decreasing trend, which may be attributed to participation in online or outdoor activities and the improvement of diet quality during the isolation associated with the coronavirus pandemic. In addition, minor changes in the results may be associated with the process of easing restrictions, which favours increased physical activity and outdoor time among children and adolescents, including the possibility of using outdoor gyms. Therefore, the results of this study suggest that promoting physical activity and healthy eating habits among young people is important to encourage them to maintain a healthy lifestyle and prevent potential health problems, especially in extraordinary situations.

Authors' contributions

PA, MŻ, ŁK have made substantial contributions to conception and design. PA, MŻ, MŻ contributed to the acquisition of data. PA, MŻ prepared analysis and interpretation of data. PA, MŻ have been involved in drafting the manuscript and revising it critically for important intellectual content. PA, MŻ, ŁK have given final approval for the version to be published.

Acknowledgements

This study has been sponsored by the University of Physical Education in Kraków (grant number 189/BS/INB/2018, 330/BS/INB/2023).

Conflict of interest

The authors have no conflicts of interest to declare.

Corresponding author

Prof. Łukasz Kryst, Department of Anthropology, Faculty of Physical Education and Sport, University of Physical Culture, 31–571 Kraków, Poland; tel. +48 605648582, fax. +48 126481546, e-mail: lkryst@poczta.onet.pl

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Załącznik nr 6.

Oświadczenie o wkładzie autorskim artykułu

Niniejszym zaświadczamy, że wkład Pauliny Artymiak w publikację:

Artymiak P, Żegleń M, Kryst Ł.

Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic.

J Phys Act Health 2024, 13;21(5):500-507. https://doi.org/190.1123/jpah.2023-0577

Impact Factor: 2,9 , Punktacja MNiSW:70

jest uznawana za 60%.

Ponadto oświadczamy, że Paulina Artymiak

☒ jest głównym współautorem niniejszej publikacji

Typ publikacji

☒ publikacja w czasopiśmie naukowym

Wkład do publikacji mgr Pauliny Artymiak:

Paulina Artymiak wzięła udział w projektowaniu oraz organizacji badań przekrojowych. Następnie przeprowadziła badania terenowe, w których skład wchodziły pomiary antropometryczne oraz testy sprawności motorycznej. Następnie, autorka zebrała wyniki do bazy danych oraz je opracowała. Ponadto, przeprowadziła analizę statystyczną i dyskusję uzyskanych wyników dotyczących oceny zmian w sprawności motorycznej młodzieży w wieku 11-15 lat z Krakowa podczas pandemii COVID-19. Poza wkładem w sekcję badawczą artykułu, autorka napisała cały manuskrypt w języku angielskim i stworzyła wszystkie tabele.

Kraków, 25.04.2025 r.

mgr Paulina Artymiak dr hab. Łukasz Kryst prof. AKF dr Magdalena Żegleń

Kraków, 25.04.2025 r.

dr Magdalena Żegleń
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2024). Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic. J Phys Act Health. 2024 Mar 13;21(5):500-507. doi: 10.1123/jpah.2023-0577
mój udział polegał na projektowaniu, organizacji badań, przeprowadzeniu oraz nadzorowaniu badań, pozyskiwaniu funduszy oraz korekcie artykułu przed publikacją. Swój udział w powstaniu publikacji oceniam na 20%.

dr Magdalena Żegleń

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Kraków, 25.04.2025 r.

dr hab. Łukasz Kryst, prof. AKF
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2024). Analysis of Changes in Physical Fitness in Children and Adolescents (11-15 Years) From Kraków (Poland) During COVID-19 Pandemic. J Phys Act Health. 2024 Mar 13;21(5):500-507. doi: 10.1123/jpah.2023-0577
mój udział polegał na projektowaniu, organizacji badań, przeprowadzeniu oraz nadzorowaniu badań, pozyskiwaniu funduszy, korekcie artykułu przed publikacją oraz byłem autorem korespondencyjnym. Swój udział w powstaniu publikacji oceniam na 20%.

dr hab. Łukasz Kryst, prof. AKF

……

Załącznik nr 7.

Oświadczenie o wkładzie autorskim artykułu

Niniejszym zaświadczamy, że wkład Pauliny Artymiak w publikację:

Artymiak P, Żegleń M, Kryst Ł.

Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic.

AnthropolAnz. 2025, 11;82(1):1-6. https://doi.org/10.1127/anthranz/2024/1746

Impact Factor: 0,4 , Punktacja MNiSW: 70

jest uznawana za 60%.

Ponadto oświadczamy, że Paulina Artymiak

☒ jest głównym współautorem niniejszej publikacji

Typ publikacji

☒ publikacja w czasopiśmie naukowym

Wkład do publikacji mgr Pauliny Artymiak:

Paulina Artymiak wzięła udział w projektowaniu oraz organizacji badań przekrojowych. Następnie przeprowadziła badania terenowe, w których skład wchodziły pomiary antropometryczne oraz testy sprawności motorycznej. Następnie, autorka zebrała wyniki do bazy danych oraz je opracowała. Ponadto, przeprowadziła analizę statystyczną i dyskusję uzyskanych wyników dotyczących oceny zmian wskaźnika BMI oraz częstości występowania nadwagi i otyłości u dzieci i młodzieży (11-15 lat) z Krakowa w okresie pandemii COVID-19. Poza wkładem w sekcję badawczą artykułu, autorka napisała cały manuskrypt w języku angielskim i stworzyła wszystkie tabele.

Kraków, 25.04.2025 r.

mgr Paulina Artymiak dr hab. Łukasz Kryst prof. AKF dr Magdalena Żegleń

Kraków, 25.04.2025 r.

dr Magdalena Żegleń
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2024). Changes in BMI and the prevalence of overweight and obesity in children and adolescents (11-15 years) from Kraków (Poland) during COVID-19 pandemic. Anthropol Anz. 2025 Feb 11;82(1):1-6. doi: 10.1127/anthranz/2024/1746
mój udział polegał na projektowaniu, przeprowadzeniu oraz nadzorowaniu badań, organizacji badań, pozyskiwaniu funduszy oraz korekcie artykułu przed publikacją. Swój udział w powstaniu publikacji oceniam na 20%.

dr Magdalena Żegleń

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Kraków, 25.04.2025 r.

dr hab. Łukasz Kryst, prof. AKF
Wydział Wychowania Fizycznego i Sportu
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Zakład Antropologii
ul. Jana Pawła II 78
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Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

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mój udział polegał na projektowaniu, organizacji badań, przeprowadzeniu oraz nadzorowaniu badań, pozyskiwaniu funduszy, korekcie artykułu przed publikacją oraz byłem autorem korespondencyjnym. Swój udział w powstaniu publikacji oceniam na 20%.

dr hab. Łukasz Kryst, prof. AKF

……

Załącznik nr 8.

Oświadczenie o wkładzie autorskim artykułu

Niniejszym zaświadczamy, że wkład Pauliny Artymiak w publikację:

Artymiak P, Żegleń M, Kryst Ł.

The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland).

Pediatr Obes. 2024, 19(10):e13160. https://doi.org/10.1111/ijpo.13160

Impact Factor: 3,910 , Punktacja MNiSW: 100

jest uznawana za 60%.

Ponadto oświadczamy, że Paulina Artymiak

☒ jest głównym współautorem niniejszej publikacji

Typ publikacji

☒ publikacja w czasopiśmie naukowym

Wkład do publikacji mgr Pauliny Artymiak:

Paulina Artymiak wzięła udział w projektowaniu oraz organizacji badań przekrojowych. Następnie przeprowadziła badania terenowe, w których skład wchodziły pomiary antropometryczne oraz testy sprawności motorycznej. Następnie, autorka zebrała wyniki do bazy danych oraz je opracowała. Ponadto, przeprowadziła analizę statystyczną i dyskusję uzyskanych wyników dotyczących oceny zmian w rozmieszczeniu tkanki tłuszczowej i grubości fałdów skórno-tłuszczowych wśród nastolatków w wieku 11-15 lat z Krakowa w trakcie pandemii COVID-19. Poza wkładem w sekcję badawczą artykułu, autorka napisała cały manuskrypt w języku angielskim i stworzyła wszystkie tabele.

Kraków, 25.04.2025 r.

mgr Paulina Artymiak dr hab. Łukasz Kryst prof. AKF dr Magdalena Żegleń

Kraków, 25.04.2025 r.

dr Magdalena Żegleń
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
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ul. Jana Pawła II 78
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Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2024). The effect of the COVID-19 pandemic lockdown on the distribution of fat tissue and skinfold thickness in adolescents from Kraków (Poland). Pediatr Obes. 2024 Oct;19(10):e13160. doi: 10.1111/ijpo.13160;
mój udział polegał na projektowaniu, przeprowadzeniu oraz nadzorowaniu badań, organizacji badań, pozyskiwaniu funduszy oraz korekcie artykułu przed publikacją. Swój udział w powstaniu publikacji oceniam na 20%.

dr Magdalena Żegleń

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Kraków, 25.04.2025 r.

dr hab. Łukasz Kryst, prof. AKF
Wydział Wychowania Fizycznego i Sportu
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Oświadczenie współautorstwa publikacji

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mój udział polegał na projektowaniu, organizacji badań, przeprowadzeniu oraz nadzorowaniu badań, pozyskiwaniu funduszy, korekcie artykułu przed publikacją oraz byłem autorem korespondencyjnym. Swój udział w powstaniu publikacji oceniam na 20%.

dr hab. Łukasz Kryst, prof. AKF

……

Załącznik nr 9.

Oświadczenie o wkładzie autorskim artykułu

Niniejszym zaświadczamy, że wkład Pauliny Artymiak w publikację:

Artymiak P, Żegleń M, Kryst Ł.

The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population.

Am J Hum Biol. 2025, 37(1):e24182. https://doi.org/10.1002/ajhb.24182

Impact Factor: 1,6 , Punktacja MNiSW: 70

jest uznawana za 60%.

Ponadto oświadczamy, że Paulina Artymiak

☒ jest głównym współautorem niniejszej publikacji

Typ publikacji

☒ publikacja w czasopiśmie naukowym

Wkład do publikacji mgr Pauliny Artymiak:

Paulina Artymiak wzięła udział w projektowaniu oraz organizacji badań przekrojowych. Następnie przeprowadziła badania terenowe, w których skład wchodziły pomiary antropometryczne oraz testy sprawności motorycznej. Następnie, autorka zebrała wyniki do bazy danych oraz je opracowała. Ponadto, przeprowadziła analizę statystyczną i dyskusję uzyskanych wyników dotyczących oceny zmian obwodu talii i bioder oraz wskaźników WHR i WHtR u młodzieży w wieku 11-15 lat z Krakowa w okresie pandemii COVID-19. Poza wkładem w sekcję badawczą artykułu, autorka napisała cały manuskrypt w języku angielskim i stworzyła wszystkie tabele.

Kraków, 25.04.2025 r.

mgr Paulina Artymiak dr hab. Łukasz Kryst prof. AKF dr Magdalena Żegleń

Kraków, 25.04.2025 r.

dr Magdalena Żegleń
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2025). The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population. Am J Hum Biol. 2025 Jan;37(1):e24182. doi: 10.1002/ajhb.24182;
mój udział polegał na projektowaniu, przeprowadzeniu oraz nadzorowaniu badań, organizacji badań, pozyskiwaniu funduszy oraz korekcie artykułu przed publikacją. Swój udział w powstaniu publikacji oceniam na 20%.

dr Magdalena Żegleń

……

Kraków, 25.04.2025 r.

dr hab. Łukasz Kryst, prof. AKF
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, Kryst Ł. (2025). The Impact of the COVID-19 Pandemic on Waist and Hip Circumference and Selected Indicators Related to It Among Adolescents From the Kraków (Poland) Population. Am J Hum Biol. 2025 Jan;37(1):e24182. doi: 10.1002/ajhb.24182
mój udział polegał na projektowaniu, organizacji badań, przeprowadzeniu oraz nadzorowaniu badań, pozyskiwaniu funduszy, korekcie artykułu przed publikacją oraz byłem autorem korespondencyjnym. Swój udział w powstaniu publikacji oceniam na 20%.

dr hab. Łukasz Kryst, prof. AKF

……

Załącznik nr 10.

Oświadczenie o wkładzie autorskim artykułu

Niniejszym zaświadczamy, że wkład Pauliny Artymiak w publikację:

Artymiak P, Żegleń M, Kryst Ł.

Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11–15 from Kraków during the COVID-19 pandemic.

Anthropological Review, 87(4), 55–67. https://doi.org/10.18778/1898-6773.87.4.04

Impact Factor: -, Punktacja MNiSW: 70

jest uznawana za 60%.

Ponadto oświadczamy, że Paulina Artymiak

☒ jest głównym współautorem niniejszej publikacji

Typ publikacji

☒ publikacja w czasopiśmie naukowym

Wkład do publikacji mgr Pauliny Artymiak:

Paulina Artymiak wzięła udział w projektowaniu oraz organizacji badań przekrojowych. Następnie przeprowadziła badania terenowe, w których skład wchodziły pomiary antropometryczne oraz testy sprawności motorycznej. Następnie, autorka zebrała wyniki do bazy danych oraz je opracowała. Ponadto, przeprowadziła analizę statystyczną i dyskusję uzyskanych wyników dotyczących oceny zmian w składzie ciała, ze szczególnym uwzględnieniem masy mięśnioweji tkanki tłuszczowej, wśród nastolatków w wieku 11–15 lat z Krakowa w trakcie pandemii COVID-19. Poza wkładem w sekcję badawczą artykułu, autorka napisała cały manuskrypt w języku angielskim i stworzyła wszystkie tabele i ryciny.

Kraków, 25.04.2025 r.

mgr Paulina Artymiak dr hab. Łukasz Kryst prof. AKF dr Magdalena Żegleń

Kraków, 25.04.2025 r.

dr Magdalena Żegleń
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
ul. Jana Pawła II 78
31-371 Kraków

Dotyczy wniosku o przeprowadzenie postępowania doktorskiego mgr Pauliny Artymiak

Oświadczenie współautorstwa publikacji

Oświadczam, że w powstaniu publikacji: Artymiak P, Żegleń M, KrystŁ. (2025). Changes in body composition (muscle mass and adipose tissue) among adolescents aged 11-15 from Kraków during the COVID-19 pandemic. *Anthropological Review*, *87*(4), 55–67. https://doi.org/10.18778/1898-6773.87.4.04.
mój udział polegał na projektowaniu, przeprowadzeniu oraz nadzorowaniu badań, organizacji badań, pozyskiwaniu funduszy oraz korekcie artykułu przed publikacją. Swój udział w powstaniu publikacji oceniam na 20%.

dr Magdalena Żegleń

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dr hab. Łukasz Kryst, prof. AKF

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