Akademia Wychowania Fizycznego

im. Bronisława Czecha w Krakowie

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Rozprawa doktorska (doctoral dissertation)

zatytułowana:

„Analiza obciążeń treningowych polskich kolarzy szosowych kategorii junior z uwzględnieniem ich wpływu na jakość podstawowych wzorców ruchowych, stabilność posturalną oraz wydolność fizyczną"

titled:

"Analysis of training loads in Polish junior road cyclists with consideration of their impact on the quality of basic movement patterns, postural stability, and physical fitness"

Promotor: prof. dr hab. Tadeusz Ambroży

Kraków, 2024 r.

„Nie wiem, jak wyglądam w oczach świata, lecz dla siebie jestem tylko chłopcem bawiącym się na morskim brzegu, pochylającym się i znajdującym piękniejszą muszelkę lub kamień gładszy niż inne, podczas gdy wielki ocean prawdy jest ciągle zakryty przede mną"

-Ponoć są to słowa Isaaca Newtona-

Spis treści

1. Streszczenie

Niniejsza rozprawa została przygotowana w formie cyklu 3 powiązanych tematycznie artykułów naukowych (oznaczonych jako A, B i C), które zostały opublikowane w recenzowanych czasopismach. Koncentrują się one na obciążeniach treningowych realizowanych przez młodych kolarzy szosowych w okresie przygotowawczym i ich wpływie na jakość podstawowych wzorców ruchowych, stabilność posturalną i wydolność fizyczną.

Publikacja A dotyczy wpływu treningu kolarskiego na jakość podstawowych wzorców ruchowych i wielkość obszaru stabilności posturalnej. Wyniki badania wskazują, że dojrzewający kolarze mogą doświadczać deficytów funkcjonalnych, szczególnie w rejonie kompleksu lędźwiowo-miedniczo-biodrowego oraz tułowia. Badanie podkreśla potrzebę włączania do ich programów treningowych specjalistycznych ćwiczeń korygujących.

Publikacja B ocenia wpływ zmęczenia beztlenowego na sprawność działania systemu kontroli równowagi posturalnej. Po maksymalnym 30-sekundowym wysiłku rowerowym u badanych kolarzy szosowych zaobserwowano znaczący spadek sprawności tego systemu. Obserwacja ta powinna być użyteczna dla trenerów i organizatorów wyścigów kolarskich, ponieważ można ją wykorzystać w planowaniu działań mających na celu zmniejszenie liczby upadków i ich konsekwencji podczas zawodów i treningów.

Publikacja C skupia się na analizie wielkości i struktury obciążeń treningowych oraz ich wpływie na wydolność tlenową i beztlenową. Po 18-tygodniowym okresie przygotowawczym, podczas którego kolarze realizowali obciążenia o niskiej objętości, a także o piramidalnym i niespolaryzowanym rozkładzie intensywności, nie zaobserwowano znaczącej poprawy wydolności aerobowej i anaerobowej. Wyniki podkreślają potrzebę dalszych badań nad optymalizacją obciążeń treningowych.

Podsumowując, rozprawa dostarcza cennych informacji na temat wpływu treningu kolarskiego na różne aspekty motoryki młodych sportowców. Ponadto, podkreśla potrzebę indywidualnego podejścia do treningu, uwzględniającego specyficzne potrzeby kolarzy, aby efektywnie podnosić wyniki sportowe i obniżać ryzyko wystąpienia urazu.

Słowa kluczowe: dojrzewający kolarze szosowi, obciążenia treningowe, stabilność posturalna, FMS, YBT-LQ, urazy sportowe, wydolność tlenowa, wydolność beztlenowa

2. Abstract

The doctoral dissertation was prepared in the form of a cycle of 3 thematically related scientific articles (marked as A, B, and C), which were published in peer-reviewed journals. They focus on the training loads carried out by young road cyclists during the preparatory period and their impact on the quality of basic movement patterns, postural stability, and physical fitness.

Publication A discusses the impact of cycling training on the quality of basic movement patterns and the limits of postural stability. The study's results indicate that maturing cyclists may experience functional deficits, especially in the lumbar-pelvic-hip complex and trunk areas. The study highlights the need to include specialized corrective exercises in their training programs.

Publication B assesses the impact of anaerobic fatigue on the efficiency of the postural balance control system. After a maximal 30-second cycling effort, a significant decrease in the efficiency of this system was observed in the road cyclists studied. This should be useful information for coaches and cycling event organizers, as it can be used in planning activities aimed at reducing the number of falls and their consequences during competitions and training.

Publication C focuses on the analysis of the size and structure of training loads and their impact on aerobic and anaerobic fitness. After an 18-week preparatory period, during which cyclists undertook loads of low volume, as well as pyramid and non-polarized intensity distribution, no significant improvement in aerobic and anaerobic fitness was observed. The observation results underscore the need for further research on optimizing training loads.

In summary, the dissertation provides valuable information on the impact of cycling training on various aspects of young athletes' motor skills. It highlights the need for an individual approach to training, taking into account the specific needs of cyclists, to optimize their sports results and minimize the risk of injuries.

Key words*:* adolescent road cyclists, training loads, postural stability, FMS, YBT-LQ, sports injuries, aerobic fitness, anaerobic fitness

3. Spis publikacji wchodzących w skład cyklu dysertacyjnego

Rozprawa doktorska została przygotowana w formie cyklu powiązanych tematycznie artykułów naukowych. We wszystkich wskazanych pracach, na każdym etapie ich powstawania, autor dysertacji pełnił wiodącą rolę (patrz strony od 51 do 53). W skład cyklu wchodzą następujące artykuły opublikowane w czasopismach recenzowanych:

A. Zając B, Mika A, Gaj PK, Ambroży T. (2022). Does Cycling Training Reduce Quality of Functional Movement Motor Patterns and Dynamic Postural Control in Adolescent Cyclists? A Pilot Study. *International Journal of Environmental Research and Public Health*, 19(19), 12109.
DOI: https://doi.org/10.3390/ijerph191912109.
Impact Factor: 4.614, Punktacja MEiN: 140

B. Zając B, Mika A, Gaj PK, Ambroży T. (2023). Effects of Anaerobic Fatigue Induced by Sport-Specific Exercise on Postural Control in Highly-Trained Adolescent Road Cyclists. *Applied Sciences*, 13(3), 1697. DOI: https://doi.org/10.3390/app13031697.
Impact Factor: 2.838, Punktacja MEiN: 70

C. Zając B, Gaj PK, Ambroży T. (2024). Analysis of training loads in polish adolescent road cyclists in the preparatory period and their effects on physical fitness. *Journal of Kinesiology and Exercise Science*, 104(35). DOI: 10.5604/01.3001.0053.9657.
Punktacja MEiN: 70

Ponadto, autor dysertacji jest współautorem następujących artykułów naukowych:

D. Zając B, Mirek W, Ambroży T. (2020). The effects of an 18-week training programme on movement economy of a long-distance runner – a case study. *Journal of Kinesiology and Exercise Science,* 30(89). DOI: 10.5604/01.3001.0014.5850.
Punktacja MEiN: 20

E. Zając B, Sulowska-Daszyk I, Mika A, Stolarczyk A, Rosłoniec E, Królikowska A, Rzepko M, Oleksy Ł. (2021). Reliability of Pelvic Floor Muscle Assessment with Transabdominal Ultrasound in Young Nulliparous Women. *Journal of Clinical Medicine*. 10(15), 3449.
DOI: https://doi.org/10.3390/jcm10153449.
Impact Factor: 4.964, Punktacja MEiN: 140

F. Janczarzyk D, Jamka K, Mikołajczyk E, Zając B. (2023). Comparing the Effects of a Series of Ischaemic Compression Therapy and Muscle Energy Techniques on Pain Threshold and Muscle Tension in People with Upper Crossed Syndrome. *Medical Rehabilitation.* 27(1).
DOI: 10.5604/01.3001.0015.8749.
Punktacja MEiN: 100

G. Zając B, Gaj PK, Zięba J. (2022). Concurrent Validity and Inter-Rater Reliability of Hand-Held Measurements of Maximal Sprint Speed. *Journal of Kinesiology and Exercise Science,* 100(32). DOI: 10.5604/01.3001.0016.1225.

Punktacja MEiN: 70

H. Zając B, Olszewski M, Mika A, Maciejczyk M. (2023). Do Highly Trained Mountain Runners Differ from Recreational Active Non-Runners on Range of Motion and Strength in the Hip and Ankle as Well as Postural Control?. *Journal of Clinical Medicine*, 12(7), 2715. DOI: 10.3390/jcm12072715.

Impact Factor: 4.964, Punktacja MEiN: 140

I. Olszewski M, Zając B, Golec J. (2023). Cross cultural adaptation, reliability and validity of the Polish version of the Cumberland Ankle Instability Tool. *Disability and Rehabilitation*, 68. DOI: 10.1080/09638288.2023.2232719.

Impact Factor: 2.439, Punktacja MEiN: 70

J. Ptaszek B, Podsiadło S, Czerwińska-Ledwig O, Zając B, Niżankowski R, Mika P, Teległów A. (2023). The Influence of Interval Training Combined with Occlusion and Cooling on Selected Indicators of Blood, Muscle Metabolism and Oxidative Stress. *Journal of Clinical Medicine*, 12(24), 7636. DOI: https://doi.org/10.3390/jcm12247636.

Impact Factor: 3.9, Punktacja MEiN: 140

K. Sokulska N, Zając B, Gaj PK. (2024). Assessing Differences and Implications of Two Methods for Calculating Outcomes in the Lower Quarter Y-Balance Test. *Medical Rehabilitation,* 27(3). DOI: 10.5604/01.3001.0054.2800.

Punktacja MEiN: 100

L. Olszewski M, Zając B, Mika A, Golec J. (2023). Ankle Dorsiflexion Range of Motion and Hip Abductor Strength Can Predict Lower Quarter Y-Balance Test Performance in Healthy Males. *Journal of Bodywork & Movement Therapies*, 38. DOI: 10.1016/j.jbmt.2024.03.053.

Impact Factor: 1.4, Punktacja MEiN: 70

M. Zając B. (2024). Analysis of Course of Changes in Blood Lactate Concentration in Response to Graded Exercise Test and Modified Wingate Test in Adolescent Road Cyclists. *Journal of Clinical Medicine,* 13(2), 535. DOI: https://doi.org/10.3390/jcm13020535.

Impact Factor: 3.9, Punktacja MEiN: 140

N. Ptaszek B, Podsiadło S, Klimala K, Zając B, Niżankowski R, Mika P, Teległów A. (2024) The Influence of Interval Training Combined With Occlusion and Cooling on Selected Hemorheological Blood Parameters in Young Healthy People. *Medical Rehabilitation,* 27(3). DOI: 10.5604/01.3001.0054.2815.

Punktacja MEiN: 100

*W/w wartości punktowe są wartościami obowiązującymi w momencie publikacji.

4. Problem badawczy łączący publikacje i jego uzasadnienie

Kolarstwo szosowe to niezwykle fascynująca dyscyplina sportowa, która wyróżnia się wśród innych dyscyplin wytrzymałościowych dzięki obszernemu spektrum konkurencji oraz wysokim wymaganiom fizycznym stawianym przed zawodnikami. Unikalną cechą tej dyscypliny jest zestaw czynników determinujących poziom wyników sportowych. Obejmują one nie tylko wydolność fizyczną, efektywność pracy narządu ruchu i wytrzymałość[1], ale również umiejętności techniczne i taktyczne[2]. Istotnymi elementami są także kompetencje w zakresie pracy zespołowej, wdrażane rozwiązania żywieniowe i strategie odnowy biologicznej, a także aspekty natury psychologicznej.

Pierwszą i najstarszą konkurencją kolarstwa szosowego jest wyścig klasyczny, podczas którego około 180 zawodników bezpośrednio rywalizować może na trasach o długościach dochodzących do 300 km w kategorii elity mężczyzn[3]. Na chwilę pisania dysertacji, najdłuższym wyścigiem klasycznym zaliczanym do cyklu UCI World Tour jest włoski monument Milano-Sanremo[4]. Interesujący jest fakt, że rywalizacja na tak długich dystansach bywa niezwykle intensywna, na co wskazują dane z wyścigów, takie jak średnia liczba przyspieszeń peletonu wymagająca od sportowców pracy o energetyce beztlenowej (około 20-70)[5], średnie prędkości osiągane przez zawodników (~45 km/h)[6], a także wielkości generowanej mocy przez finiszujących kolarzy (~1200 W, ~17 W/kg)[7]. Dodatkowo, oprócz ogromnego dystansu i zmiennej intensywności, kolarze szosowi często muszą stawiać czoła dodatkowym wyzwaniom, takim jak zmienna i niekiedy śliska nawierzchnia, wąskie i kręte uliczki, trudne technicznie zjazdy, a także nieprzewidywalne warunki atmosferyczne. Jednym z najbardziej

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[1] Faria EW, Parker DL, Faria IE. (2005). *The Science of Cycling*. Sports Medicine, 35, 313–337.
[2] Poliszczuk, D. (1996). *Kolarstwo: teoria i praktyka treningu*. Warszawa.
[3] Źródło internetowe: *https://www.uci.org/* [dostęp: 15.11.2023 r.]
[4] Źródło internetowe: *https://www.milanosanremo.it/en/* [dostęp: 15.11.2023 r.]
[5] Ebert TR, Martin DT, Stephens B, Withers RT. (2006). *Power Output During a Professional Men's Road-Cycling Tour*. International Journal of Sports Physiology and Performance, 1(4), 324–335.
[6] Lucía A, Hoyos J, Chicharro JL. (2001). *Physiology of Professional Road Cycling*. Sports Medicine, 31(5), 325–337.
[7] Menaspà P, Quod M, Martin DT, Peiffer JJ, Abbiss CR. (2015). *Physical demands of sprinting in professional road cycling*. International Journal of Sports Medicine, 36(13), 1058–1062.

charakterystycznych pod tym względem wyścigów klasycznych jest francuski Paris-Roubaix, znany jako „Piekło Północy". Charakteryzuje go duża liczba kilometrów (ok. 50, co stanowi ok. 1/5 długości wyścigu) prowadzących po wąskich i krętych drużkach brukowych wykonanych z kamienia polnego, zwanego „kocimi łbami"[8]. Kolejne dwie konkurencje to jazda indywidualna na czas (ITT) oraz jazda drużynowa na czas (TTT), w których celem zarówno zawodnika, jak i drużyny, jest pokonanie określonej trasy (najczęściej o długości rzędu kilkunastu-kilkudziesięciu kilometrów) w jak najkrótszym czasie. Charakterystyczną cechą ITT i TTT jest wykorzystywanie przez kolarzy wysoko zaawansowanych i bardzo charakterystycznych rowerów, kasków i strojów, które zostały zaprojektowane w celu minimalizacji oporów powietrza. Ostatnią konkurencją jest wyścig wieloetapowy, będący kombinacją wyżej wymienionych form rozgrywaną na przestrzeni co najmniej dwóch dni. Do najdłuższych, najtrudniejszych i najbardziej prestiżowych wyścigów wieloetapowych zalicza się tzw. grand toury (Giro d'Italia, Tour de France, La Vuelta a España), podczas których kolarze pokonują ok. 3500-4000 km w przeciągu około 3 tygodni[9]. Warto zaznaczyć, że wyścigi wieloetapowe to wyjątkowa próba umiejętności sportowców. Mieszanka etapów o różnej charakterystyce, sprawia że zawodnicy muszą być wszechstronni i potrafią dostosowywać się do różnorodnych warunków trasy i sytuacji.

Charakterystyka walki sportowej wymusza na kolarzach stosowanie obciążeń treningowych o względnie określonej wielkości i strukturze, zgodnie z zasadą specyficzności procesu treningowego. Z tego powodu nie dziwi fakt, że kolarze wykonują dużą ilość pracy treningowej na rowerze, przy czym należy zaznaczyć, że przeciętna objętość treningu u seniorów wynosi ok. 20 godzin na tydzień[10]. Na podstawie tego faktu, autor dysertacji wraz ze współautorami publikacji A przyjął hipotezę, zakładając, że

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[8] Duc S, Puel F. (2016). *Vibration exposure on cobbles sectors during Paris-Roubaix*. Journal of Science and Cycling, 5(2), 19-20.

[9] Sanders D, van Erp T, de Koning JJ. (2019). *Intensity and load characteristics of professional road cycling: differences between men's and women's races*. International Journal of Sports Physiology and Performance, 14(3), 296-302.

[10] Muriel X, Courel-Ibáñez J, Cerezuela-Espejo V, Pallarés, JG. (2021). *Training Load and Performance Impairments in Professional Cyclists During COVID-19 Lockdown.* International Journal of Sports Physiology and Performance, 16(5), 735-738.

trening kolarski, który związany jest z koniecznością długotrwałego przebywania w specyficznej pozycji rowerowej[11] w połączeniu z wysiłkiem fizycznym prowadzi do dysfunkcji narządu ruchu, manifestujących się obniżoną jakością podstawowych wzorców ruchowych. Autorzy publikacji A uznali, że weryfikacja postawionej hipotezy może być użyteczna, ponieważ pozwoli pozyskać informacje przydatne w kontekście badań ukierunkowanych na poznanie mechanizmów powstawania urazów, jak również planowania praktycznych działań związanych z prewencją urazów.

Jednym z kluczowych czynników umożliwiających człowiekowi utrzymanie równowagi podczas jazdy na rowerze jest obecność w jego organizmie wysoko rozwiniętego systemu kontroli równowagi. System ten, w warunkach rywalizacji sportowej i treningu, jest intensywnie eksploatowany ze względu na mnogość czynników destabilizujących, zarówno wewnętrznych (takich jak reakcje fizjologiczne na wysiłek o różnym podłożu energetycznym), jak i zewnętrznych (takich jak zmienna, czasem śliska nawierzchnia, wąskie i kręte uliczki, technicznie trudne zjazdy, obecność innych zawodników lub uczestników ruchu na drodze)[12]. Szczególnie trudnym wyzwaniem wydają się być nierzadkie sytuacje, w których kolarz musi sobie radzić zarówno z dużym zmęczeniem, jak i trudnym technicznie sektorem trasy (np. kręty zjazd z przełęczy po finiszu na górską premię). Mając to na uwadze, autor dysertacji wraz ze współautorami publikacji B przyjął hipotezę, zakładając, że sprawność działania systemu kontroli równowagi kolarzy szosowych obniża się w warunkach zmęczenia wywołanego wysiłkiem o energetyce beztlenowej, co manifestować się będzie zmianami wielkości parametrów charakteryzujących obszar wychwiań środka nacisku stóp na podłoże w pozycji stojącej. Autorzy publikacji B podjęli się weryfikacji postawionej hipotezy ponieważ, uznali, że poznanie reakcji systemu kontroli równowagi na zmęczenie może być użyteczne w kontekście planowania działań ukierunkowanych na redukcję liczby upadków, które wymieniane są jako jedna z głównych przyczyn urazów wśród

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[11] Muyor JM, López-Miñarro PA, Alacid F. (2011). *Spinal posture of thoracic and lumbar spine and pelvic tilt in highly trained cyclists*. Journal of Sports Science & Medicine, 10(2), 355.

[12] Paillard T. (2012). *Effects of general and local fatigue on postural control: a review*. Neuroscience & Biobehavioral Reviews, 36(1), 162-176.

kolarzy szosowych[13]. Działania takie mogą obejmować np. zabezpieczanie newralgicznych odcinków wyścigu lub wdrażanie do programów treningowych kolarzy ćwiczeń ukierunkowanych na kształtowanie stabilności posturalnej w warunkach zmęczenia.

Obciążenia treningowe stanowią kluczowy czynnik stymulujący rozwój możliwości wysiłkowych sportowca. W związku z tym, raportowanie ich wielkości i struktury, a także opisywanie efektów, jakie przynoszą — na przykład w postaci zmian w wydolności fizycznej lub wynikach sportowych — może być cenne zarówno dla praktyków, jak i naukowców. Jeśli dane wskazują na skuteczność danego programu treningowego, warto rozważyć jego szczegółową analizę i szersze zastosowanie. Z drugiej strony, jeśli obserwacje wskazują na nieskuteczność programu, powinno to zachęcać do jego unikania. Mając na uwadze powyższe, autorzy publikacji C, postawili sobie za cel pracy analizę obciążeń treningowych realizowanych podczas 18-tygodniowego okresu przygotowawczego i ocenę ich wpływu na wydolność fizyczną polskich dorastających kolarzy szosowych o wysokim poziomie sportowym. Autorzy publikacji C postanowili zrealizować założony cel z dwóch powodów. Pierwszym z nich była chęć wzbogacenia zasobu wiedzy o informacje na temat wielkości i struktury obciążeń treningowych stosowanych u polskich dojrzewających kolarzy szosowych, a także wywieranych przez nie efektów. Drugim powodem, a zasadzie skutkiem ubocznym, była możliwość dostarczenia szkoleniowcom informacji, użytecznych z perspektywy praktyki treningowej.

Reasumując, wspólnym mianownikiem publikacji A, B i C jest dążenie do lepszego poznania obciążeń treningowych realizowanych przez dojrzewających kolarzy szosowych i zrozumienia ich wpływu na wydolność fizyczną, stan narządu ruchu, a także działanie systemu kontroli równowagi w warunkach zmęczenia. W związku z tym, przeprowadzone badania umożliwiły poszerzenie zakresu wiedzy w dziedzinie nauk o kulturze fizycznej oraz dostarczenie praktycznych informacji dla trenerów i zawodników, co może przyczynić się do poprawy wyników w kolarstwie szosowym.

[13] Schwellnus MP, Derman EW. (2005). *Common injuries in cycling: Prevention, diagnosis and management*. South African Family Practice, 47(7), 14-19.

5. Research problem connecting the publications and its justification

Road cycling is an incredibly fascinating sport, distinguished among other endurance disciplines by its wide spectrum of competitive forms and the high physical demands placed on athletes. A unique feature of this discipline is the set of factors determining the level of sports performance. These include not only physical fitness, efficiency of the motor system, and endurance[1], but also technical and tactical skills[2]. Important elements also include competencies in teamwork, implemented nutritional solutions and strategies for biological regeneration, as well as psychological aspects.

The first and oldest form of road cycling is the classic race, during which about 180 competitors can directly compete on routes that can now be close to 300 km in length in the elite men's category[3]. At the time of writing this dissertation, the longest classic race included in the UCI World Tour is the Italian monument Milano-Sanremo[4]. An interesting aspect is that competition over such long distances can be incredibly intense, as evidenced by race data such as the average number of accelerations in the peloton requiring athletes to work anaerobically (~20-70)[5], average speeds achieved by cyclists (~45 km/h)[6], and the power generated by finishing riders (~1200 W, ~17 W/kg)[7]. Additionally, besides the immense distance and varying intensity, road cyclists often face additional challenges such as variable and sometimes slippery road surfaces, narrow and winding streets, technically challenging descents, and unpredictable weather conditions. One of the most specific races in this regard is the French Paris-Roubaix, known as the "Hell of the North." It is characterized by a large number of kilometers (about 50, which is about 1/5 of the length of the race) leading through narrow and

[1] Faria EW, Parker DL, Faria IE. (2005). *The Science of Cycling*. Sports Medicine, 35, 313–337.
[2] Poliszczuk, D. (1996). *Kolarstwo: teoria i praktyka treningu*. Warszawa.
[3] Źródło internetowe: *https://www.uci.org/* [dostęp: 15.11.2023 r.]
[4] Źródło internetowe: *https://www.milanosanremo.it/en/* [dostęp: 15.11.2023 r.]
[5] Ebert TR, Martin DT, Stephens B, Withers RT. (2006). *Power Output During a Professional Men's Road-Cycling Tour*. International Journal of Sports Physiology and Performance, 1(4), 324–335.
[6] Lucía A, Hoyos J, Chicharro JL. (2001). *Physiology of Professional Road Cycling*. Sports Medicine, 31(5), 325–337.
[7] Menaspà P, Quod M, Martin DT, Peiffer JJ, Abbiss CR. (2015). *Physical demands of sprinting in professional road cycling*. International Journal of Sports Medicine, 36(13), 1058–1062.

winding cobblestone paths made of fieldstone, known as "cobbles"[8]. The next two forms are the individual time trial (ITT) and the team time trial (TTT), where the goal of both the rider and the team is to cover a specified route (usually ranging from several to several dozen kilometers) in the shortest possible time. A characteristic feature of ITT and TTT is the use of highly advanced and very distinctive bicycles, helmets, and outfits by cyclists, which have been designed to minimize air resistance. The last form is the multi-stage race, which is a combination of the above-mentioned forms played out over at least two days. Among the longest, most difficult, and most prestigious multi-stage races are the so-called grand tours (Giro d'Italia, Tour de France, La Vuelta a España), during which cyclists cover about 3500-4000 km over approximately 3 weeks[9]. It is worth noting that multi-stage races are a unique test of athletes' skills. The mix of stages with different characteristics means that competitors must be versatile and able to adapt to various route conditions and situations.

The characteristics of competitive cycling force cyclists to apply training loads of a relatively specific magnitude and structure, in accordance with the principle of specificity in the training process. Therefore, it is not surprising that cyclists perform a large amount of training work on the bike, noting that the average training volume for seniors is about 20 hours per week[10]. Based on this fact, the author of the dissertation, along with co-authors of publication A, assumed the hypothesis that cycling training, which is associated with the necessity of prolonged maintenance of a specific cycling position[11] combined with physical exertion, leads to dysfunctions of the musculoskeletal system, manifesting as reduced quality of basic movement patterns. The authors of publication A considered that the verification of this hypothesis could be valuable,

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[8] Duc S, Puel F. (2016). *Vibration exposure on cobbles sectors during Paris-Roubaix*. Journal of Science and Cycling, 5(2), 19-20.

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as it would provide information useful in the context of research aimed at understanding the mechanisms of injury occurrence, as well as planning practical actions related to injury prevention.

One of the key factors enabling a person to maintain balance while cycling is the presence of a highly developed balance control system in the human body. This system, under the conditions of sports competition and training, is intensively exploited due to the multitude of destabilizing factors, both internal (such as physiological reactions to effort of various energetic backgrounds) and external (such as variable, sometimes slippery surfaces, narrow and winding streets, technically difficult descents, presence of other competitors or traffic participants on the road)[12]. Particularly challenging are not uncommon situations where a cyclist must cope with both significant fatigue and technically difficult sections of the route (e.g., descending from a mountain pass after a mountain sprint finish). Based on this observation, the author of the dissertation, together with co-authors of publication B, adopted the hypothesis that the quality of the balance control system in road cyclists decreases under conditions of fatigue caused by specific anaerobic effort, which should manifest as changes in the size of parameters characterizing the area of foot pressure center swings on the ground in a standing position. The authors of publication B undertook the verification of this hypothesis because understanding the balance control system's reaction to anaerobic fatigue can be valuable in the context of planning actions aimed at reducing the negative consequences of falls during races, which are the main cause of injuries among road cyclists[13]. Such actions may include, for example, securing appropriate sectors of the route.

The primary factor stimulating the development of an athlete's exercise capacity is training loads. Therefore, reporting their magnitude and structure, combined with the effects they produced, such as changes in physical fitness or sports results, can be

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[12] Paillard T. (2012). *Effects of general and local fatigue on postural control: a review*. Neuroscience & Biobehavioral Reviews, 36(1), 162-176.

[13] Schwellnus MP, Derman EW. (2005). *Common injuries in cycling: Prevention, diagnosis and management*. South African Family Practice, 47(7), 14-19.

valuable for both practitioners and scientists. Such data can serve as a starting point for designing training programs and explaining their positive effects (improvement in sports results), lack of effects (stagnation of results), as well as understanding and preventing their negative consequences (injury, overtraining). With the above in mind, the authors of publication C set out to analyze training loads applied during an 18-week preparatory period and assess their impact on the physical fitness of Polish adolescent road cyclists at a high sports level. The authors of publication C decided to achieve this goal for two reasons. The first is to enrich the body of knowledge with information about the magnitude and structure of training loads used in developing road cyclists, as interestingly, there is not too much data of this type available. The second reason, or rather a side effect, was the possibility of providing athletes and coaches with information that can be used in the training process.

In summary, the common denominator of publications A, B, and C is the pursuit of better understanding the training loads undertaken by adolescent road cyclists and comprehending their impact on physical fitness, the state of the musculoskeletal system, and the functioning of the balance control system under fatigue conditions. Consequently, the conducted research has enabled the expansion of knowledge in the field of physical culture sciences and provided practical information for coaches and athletes, which may contribute to improving results in road cycling.

6. Publikacja A

Tytuł: Does Cycling Training Reduce Quality of Functional Movement Motor Patterns and Dynamic Postural Control in Adolescent Cyclists? A Pilot Study.

Cel pracy: (1) Ustalenie, czy trening kolarski wpływa na jakość podstawowych wzorców ruchowych i wielkość obszaru stabilności posturalnej u dorastających sportowców. (2) Określenie trafności predykcji ryzyka urazu przeciążeniowego u dorastających kolarzy szosowych za pomocą testów Functional Movement Screen (FMS) i Lower Quarter Y-balance (YBT-LQ).

Materiał i metody: W badaniu uczestniczyło 23 kolarzy szosowych w wieku od 15 do 17 lat. Jakość podstawowych wzorców ruchowych została oceniona za pomocą testu FMS, a wielkość obszaru stabilności posturalnej oceniono przy użyciu YBT-LQ. Informacje dotyczące urazów, takie jak ich liczba, lokalizacja i stopień ciężkości, pozyskano retrospektywnie za pomocą kwestionariusza ankiety, który wzorowany był na OSTRC Overuse Injury Questionnaire.

Wyniki: 30% uczestników badania wykazało wzorce ruchowe o niskiej jakości, tj. ocenione na mniej niż 2 punkty, w dwóch próbach wchodzących w skład FMS, a mianowicie w próbie przenoszenia nogi nad płotkiem oraz w próbie 'pompki'. Dla FMS, przeciętne wartości czułości, swoistości i ilorazu szans wyniosły odpowiednio 0.33, 0.62 i 0.80. Natomiast dla YBT-LQ, przeciętne wartości tych wskaźników wahały się w zakresach: czułość od 0.17 do 0.67, swoistość od 0.46 do 0.92, a iloraz szans od 0.43 do 4.50.

Wnioski: (1) Dorastający kolarze szosowi mogą wykazywać deficyty funkcjonalne w obrębie kompleksu lędźwiowo-miedniczo-biodrowego oraz tułowia, dlatego w ich treningu zaleca się uwzględnianie ćwiczeń ukierunkowanych na wzmacnianie, stabilizację i mobilizację tych segmentów ciała. (2) Autorzy pracy nie zalecają stosowania testów FMS i YBT-LQ jako narzędzi do identyfikowania kolarzy szosowych o podwyższonym ryzyku urazu przeciążeniowego.

Ograniczenia: W badaniu wzięła udział jednorodna pod względem wieku i płci, a także niewielka grupa zawodników, dlatego wyników nie należy uogólniać na szerszą populację. Badaną grupę stanowili sportowcy z dużym zróżnicowaniem doświadczenia treningowego, które jest wymieniane jako jeden z czynników ryzyka urazu. Ponadto, w projekcie nie uwzględniono grupy kontrolnej, co znacznie redukuje siłę „dowodu naukowego" pochodzącego z badania.

International Journal of
Environmental Research and Public Health

MDPI

Article

Does Cycling Training Reduce Quality of Functional Movement Motor Patterns and Dynamic Postural Control in Adolescent Cyclists? A Pilot Study

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Abstract: The aim of this study was to assess whether cycling training may influence quality of functional movement patterns and dynamic postural control. We also sought to determine if the Functional Movement Screen and Lower Quarter Y-balance tests could be predictive of injury risk among adolescent road cyclists. Twenty-three male road cyclists, aged 15–18 years, were involved in the study. Quality of functional movement patterns was assessed using the Functional Movement Screen test (FMS). Dynamic postural control was evaluated using the Lower Quarter Y-balance test (YBT-LQ). Information on injury occurrence was collected through a retrospective survey. The results showed the highest percentage of scores equalling 0 and 1 (>30% in total) in two FMS component tests: the hurdle step and trunk stability push-up. The results also demonstrated a low injury predictive value of the Functional Movement Screen (cut-off <14/21 composite score) and the Lower Quarter Y-balance test (cut-off <94% composite score and >4 cm reach distance asymmetry) in adolescent road cyclists. The most important information obtained from this study is that youth road cyclists may have functional deficits within the lumbo-pelvic-hip complex and the trunk, while neither the FMS nor the YBT-LQ test are not recommended for injury risk screening in cyclists.

Keywords: FMS test; Y-balance test; cycling training; overuse injury

Citation: Zając, B.; Mika, A.; Gaj, P.K.; Ambroży, T. Does Cycling Training Reduce Quality of Functional Movement Motor Patterns and Dynamic Postural Control in Adolescent Cyclists? A Pilot Study. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12109. https://doi.org/10.3390/ijerph191912109

Academic Editor: Paul B. Tchounwou

Received: 19 August 2022
Accepted: 21 September 2022
Published: 24 September 2022

1. Introduction

Non-traumatic (overuse) injuries are a real problem among professional and amateur road cyclists [1]. Clarsen et al. [2] showed that 94% of world class cyclists experience injuries during a 1-year period, where symptoms of both lower back pain and anterior knee pain were common, with an annual prevalence of 58% and 36%, respectively. Barrios et al. [3], in professional road cyclists, reported about five non-traumatic injuries per 100,000 covered km (mainly tendinitis of the patellar and Achilles tendon). Furthermore, during the year prior to the survey, a high level of pain and overuse injuries were observed in amateur cyclists, reaching 85 [4] and 88% [5]. What is of great significance is that each injury resulted in a loss of training time and socio-economic costs, and impeded competitive success [6–9]. Therefore, detection of specific risk factors for cyclists is crucial in decreasing the rate of sport-related musculoskeletal injuries [10,11].

Road cycling is one of the most demanding endurance sports for the body. World-class road cyclists typically train a mean of 20 h per week and cover 600 km per week [12]. During this time, they assume a characteristic cycling position to reduce aerodynamic drag [13–15], which requires extreme horizontal trunk flattening and hip flexion, achieved, in part, through anterior pelvic tilt [16]. In some studies, it has been shown that cyclists sitting on a bicycle modified the lumbar lordosis curve to kyphosis [17,18]. This situation may cause posture abnormalities such as increased standing thoracic kyphosis [19] or greater anterior pelvic tilt in a seated position [16] compared to sedentary individuals. Furthermore, San Emeterio et al. [20] found that in elite female cyclists, intense cycling training induced significant alterations in lumbopelvic movement. The specificity of training also includes mainly endurance exercise and general strengthening exercise, usually not focused on lumbo-pelvic stability and on hip mobility [21–23]. However, there are not many studies in which the impact of road cycling training on neuromuscular control and movement quality is addressed using movement-competency base tests such as the Functional Movement Screen (FMS) and/or the Lower Quarter Y-balance test (YBT-LQ). Moreover, the sensitivity and specificity of the FMS and YBT-LQ as tools for injury prediction in the population of cyclists has not been reported.

FMS is a screening test that was developed with the goal of identifying deficits in movements that may predispose an otherwise healthy person to injuries during physical activity [24,25]. FMS allows the assessment of stability and mobility within the kinetic chain of full body movement, the identification of painful patterns and body asymmetries, and the recognition of overall poor-quality movement patterns [21,24,25]. The Functional Movement Screen is inexpensive, easy to use, and shows acceptable intra- and inter-rater reliability [26,27]. However, like any tools, the FMS has limitations, i.e., task-specific evaluation criteria and high intra- and inter-individual variability in movement coordination and control [28], as well as equivocal injury predictive value of the composite score [29–36].

YBT-LQ is extensively used for injury risk identification [37], return to sport testing [38], and pre–post intervention measurement [39–41]. YBT-LQ aids the assessment of dynamic neuromuscular control and lower-extremity functional flexibility. The Lower Quarter Y-balance test, like FMS, is inexpensive, easy to use, and shows good intra- and inter-rater reliability [42]. However, the relationship between composite score, reach distance (raw and normalized), reach distance asymmetry, and injury risk remains unclear [43–49].

We have hypothesized that because of long-time exposure to specific cycling positions, in combination with a high level of physical effort, road cyclists may be prone to specific neuromuscular alternations. Therefore, the aim of this study was to assess whether cycling training influences quality of functional movement patterns and dynamic postural control. We also sought to determine if the Functional Movement Screen and Lower Quarter Y-balance tests may be predictive in injury risk assessment among adolescent road cyclists.

2. Materials and Methods

2.1. Participants

The study involved 23 male road cyclists, aged 15–18 years, recruited from students of the Sport Championship School in Świdnica, Poland. The inclusion criteria were: (i) minimum 1-year training experience; (ii) obtaining a sports result at the level of at least the second sports class (according to the standards established by the Polish Cycling Federation) in the 12 months preceding the study; (iii) average training volume above 8 h per week in the last 3 weeks before the study, registered with a sport-tester; (iv) having a current certificate from a sports medicine doctor regarding the ability to practice road cycling. The exclusion criteria were acute injuries that made it impossible to perform the tests. The characteristics of the study population are presented in Table 1.

2.2. Experimental Design

All measurements were performed by an experienced researcher during one visit at the beginning of the preparatory period. The Functional Movement Screen (FMS) and Lower Quarter Y-balance test (YBT-LQ) were performed with a 5 min break in between and in a random order. Additionally, at baseline, anthropometric measurements and information about training experience were collected. All measurements were performed between 8:00 a.m. and 4:00 p.m. in a sports hall at an ambient temperature of 20 + 1 °C. The participants were asked by e-mail not to perform intensive training sessions within 48 h prior to testing. Eighteen weeks after measurements, participants were asked to fill in a retrospective survey on the prevalence of injuries occurring since the time of the baseline tests.

Table 1. Characteristics of studied population.

	Median (Q1–Q3)	Minimum	Maximum	CQV (%)
Age [year]	16.0 (15.0–17.0)	15.0	17.0	6.3
TE [year]	5.0 (3.0–6.0)	1.0	8.0	30.0
Age in TE groups [year]				
1–4 year, $n = 9$	15.0 (15.0–16.0)	15.0	17.0	3.2
5–8 year, $n = 16$	16.5 (16.0–17.0)	15.0	17.0	3.0
Body height [cm]	178.5 (174.0–180.5)	167.5	192.0	1.8
Body mass [kg]	63.2 (60.1–67.6)	52.6	82.2	5.9
Lean body mass [kg]	53.4 (51.0–57.3)	43.9	67.1	5.9
Fat mass [kg]	9.8 (8.7–12.2)	6.5	15.1	17.9
Fat [%]	15.5 (14.5–17.9)	11.1	19.7	11.0

Q1–Q3—first and third quartiles, CQV—coefficient of quartile variation, TE—training experience.

2.3. Anthropometric Measurements

Body height was measured via an anthropometer (Metrisis, Thessaloniki, Greece). The length of the lower limbs was measured in supine position (anterosuperior iliac spine to centre of the ipsilateral medial malleolus) via a measuring tape (TK Gruppe Timo Klingler, Shenzhen, China) [50]. Body mass and fat mass were determined with a body composition multi-frequency octopolar analyser (Tanita MC 780 MA, Tokyo, Japan) using the method of electrical bioimpedance in sport mode [51]. Before measurements, the feet and hands of the subject and the analyser were cleaned and degreased.

2.4. Functional Movement Screen Test (FMS)

The purpose of the FMS test was to assess fundamental movement patterns. Participants completed seven parts of the test (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and quadruped rotary stability) using the FMS kit (Perform Better, Cranston, RI, USA) in accordance with the methodology described by Cook et al. [52,53]. Participants were given verbal instructions for task performance and were allowed three attempts for each task (maximal score was registered). Then, the scores of all seven test parts were summed, resulting in a composite score (0–21 points). Five of the seven test parts assessed asymmetry by bilateral measurements. If discrepancies existed between the left and right sides, the score for the worse side was registered. Each test component was scored on an ordinal scale (0–3 points) based on quality of movement, with three being the maximum score. A score of 2 indicated that the participants required some type of compensation or were unable to complete the entire movement. A score of 1 was given if the individual was unable to remain in the movement position throughout the movement, lost balance during the test, or did not meet the minimum criteria to score a 2. Pain during any of the FMS component tests indicated a score of 0. In addition to the seven component tests, the FMS includes three clearing tests for pain detection (shoulder internal rotation and abduction with the hand placed on the opposite shoulder, lumbar extension performed in prone press-up position, and end-range lumbar flexion in quadruped). Pain on a clearing test resulted in a score of 0 for the shoulder mobility, trunk stability push-up, or rotatory stability tests, respectively. Details on scoring for each of the component tests are provided in the works by Teyhen et al. [54] and Cook et al. [52,53]. FMS test reliability for the ICC inter-rater ranged from 0.87 to 0.89, and for the ICC intra-rater, the range was from 0.81 to 0.91 [55,56].

2.5. Lower Quarter Y-Balance Test (YBT-LQ)

The YBT-LQ test, which was applied to evaluate quality of dynamic postural control, was performed using the YBT kit (Move2Perform, Evansville, IN, USA). The participants pushed the reach indicator blocks with one foot as far as possible in three directions—anterior (A), posteromedial (PM), and posterolateral (PL)—while standing on the contralateral leg on a central platform with hands on the pelvis. Each participant was allowed six practice trials in each direction and then performed three test trials in each direction. The reach distance was recorded as the point where the participant pushed the reach indicator block closest to the central platform to the nearest 1 cm. The testing order was as follows: three trials standing on the right foot reaching in the anterior direction (right anterior reach) followed by three trials standing on the left foot reaching in the anterior direction. This procedure was repeated for the posteromedial and the posterolateral reach directions. The trail was discarded and repeated if the subject: (i) failed to maintain a unilateral stance on the platform (e.g., touched down to the floor with the reaching foot or fell off the stance platform); (ii) failed to maintain the reach foot in contact with the reach indicator on the target area while in motion (e.g., kicked the reach indicator); (iii) used the reach indicator for stance support (e.g., placed foot on top of reach indicator); (iv) failed to return the reach foot to the starting position under control; (v) broke stance foot–heel from central platform. The average of three successful test trails for each reach direction was used for data analysis. Normalised reach distance and composite scores (CS) were calculated according to the formula proposed by Bulow et al. [57]:

$$normalised\ reach\ distance = \frac{excursion\ distance}{leg\ length} \times 100\% \quad (1)$$

$$CS = \frac{RD(anterior) + RD(posteromedial) + RD(posterolateral)}{3 \times leg\ length} \times 100\% \quad (2)$$

The reported reliability of the YBT-LQ was 0.85–0.91 for the ICC intra-rater and 0.85–0.93 for ICC inter-rater [45,58].

2.6. Overuse Injury Survey

A retrospective survey was used to collect information about overuse injuries in five anatomical locations (knee, hip, back, neck, and other body areas) that occurred during the previous 18 weeks. Five questions included in Table 2 were repeated for each location. Before the survey, subjects were informed and familiarised with the definition of overuse injury (any pain or discomfort that was not directly associated with a traumatic event and was different from the normal pain associated with competitive cycling). Any physical complaint sustained by cyclists that resulted in training volume reduction was adopted as an injury criterion for sensitivity, specificity, and odds ratio calculation [59].

2.7. Statistical Analyses

Statistical analysis was performed using SPSS Statistics 26 (IBM, Armonk, NY, USA). Differences between the right and left sides (for Y-balance test reach distances and composite score) were evaluated with the *t*-test for independent samples or the Mann–Whitney's U test, depending on the assessment of normal distribution. The normality of distribution was examined via the Shapiro–Wilk test. The probability of Type I error below 0.05 was adopted as the level of significance. The median as well as the first and third quartiles were used to present the results of the study. Sensitivity, specificity, odds ratio, and 95% confidence interval were calculated according to the proposal by Altman [60] and Altman et al. [61].

Table 2. Overuse injury survey.

Question 1			
Have you experienced (location) overuse injury during the past 18 weeks?			
a. Yes		b. No	
Question 2			
How many days in total have you had difficulties due to (location) overuse injury during the past 18 weeks?			
a. 1–3 days	b. 4–7 days	c. 8–28 days	d. >28 days
Question 3			
To what extent have you reduced your training volume due to (location) overuse injury during the past 18 weeks?			
a. No reduction	b. To a minor extent	c. To a moderate extent	d. To a major extent
Question 4			
To what extent has (location) overuse injury affected your performance during the past 18 weeks?			
a. No effect	b. To a minor extent	c. To a moderate extent	d. To a major extent
Question 5			
To what extent have you experienced pain related to (location) overuse injury during past 18 weeks?			
a. To minor extent	b. To moderate extent		c. To major extent

3. Results

3.1. Functional Movement Screen Test (FMS)

The FMS test indicated a high percentage (in total >30% all cases) of scores totalling 0 and 1 in hurdle step and trunk stability push-up tests compared to the remaining tests (Table 3). The median as well as first and third quartiles of FMS composite score reached a value of 15 (13–17).

Table 3. Score distributions for FMS component tests.

	Score, N (%)			
	0	**1**	**2**	**3**
Deep squat	0 (0.0%)	1 (4.4%)	13 (56.5%)	9 (39.1%)
Hurdle step	0 (0.0%)	7 (30.4%)	16 (69.6%)	0 (0.0%)
In-line lunge	0 (0.0%)	2 (8.7%)	16 (69.6%)	5 (21.7%)
Shoulder mobility	0 (0.0%)	0 (0.0%)	3 (13.0%)	20 (87.0%)
Active straight leg raise	0 (0.0%)	0 (0.0%)	15 (65.2%)	8 (34.8%)
Trunk stability push-up	2 (8.7%)	7 (30.4%)	8 (34.8%)	6 (26.1%)
Rotatory stability	0 (0.0%)	0 (0.0%)	23 (100.0%)	0 (0.0%)

N—number of observations, (%)—percentage of observations.

3.2. Lower Quarter Y-Balance Test (LQ-YBT)

There were no demonstrated statistically significant differences between the right and left sides in the YBT-LQ composite score (Table 4). There were also no statistically significant differences between the right and left sides with regard to anterior, posterolateral, posteromedial raw (cm), and normalized (% leg length) reach distances (Table 5).

Table 4. Summary of Lower Quarter Y-balance test composite scores.

	Median	**Q1–Q3**	**Min.**	**Max.**	**CQV (%)**	***p***
YBT-LQ composite score-L (%)	97.9	96.0–101.7	78.0	104.2	2.9	NA
YBT-LQ composite score-R (%)	99.2	95.5–102.8	89.6	108.3	3.7	NA
Difference L vs. R (%)	1.53	0.67–4.05	0.12	6.47	80.5	0.622

Q1–Q3—first and third quartiles, Min.—minimum, Max.—maximum, CQV—coefficient of quartile variation, *p*—probability of Type-1 error.

Table 5. Distribution of reach distances (median as well as first and third quartiles) for all directions.

Direction	RD (cm)		Δ (cm)	p	RD (%LL)		Δ (%)	p
	L	R			L	R		
Anterior	68.2 (63.5–73.8)	69.3 (63.6–73.3)	1.83 (1.00–3.00)	0.888	74.0 (69.3–78.1)	74.0 (70.2–78.2)	2.74 (1.33–4.40)	0.888
Posterolateral	102.0 (95.1–105.3)	103.3 (98.5–106.2)	3.16 (1.25–5.08)	0.324	110.0 (103.5–115.6)	112.4 (106.4–116.7)	3.14 (1.19–5.26)	0.378
Posteromedial	103.2 (100.3–107.3)	105.3 (100.7–109.0)	2.83 (0.92–5.25)	0.630	112.3 (107.2–116.3)	113.3 (108.4–116.6)	2.60 (0.91–5.03)	0.488

RD (cm)—reach distance in centimetres, L, R—left, right leg, (%LL)—reach distance normalised to leg length, Δ—difference between left and right lower limb, *p*—probability of Type-1 error.

3.3. Overuse Injury Survey

The result of the survey showed overuse injuries in six cyclists (31.6% of valid cases). Half of them reported injuries in more than one location. A total of 12 injuries were recorded, with most of them localized in the knee (26.3% of valid cases) and back (21.1% of valid cases). All reported knee injuries lasted between 4 and 7 days. All cyclists who reported knee problems had to reduce the training load and experienced pain, at least to a moderate extent. Half of the cases regarding knee injuries affected performance. The duration of the back problems varied considerably. Half of cases with back problems did not require a reduction of training load. The majority of back injury cases experienced at least moderate pain and were forced to reduce training loads. Detailed numerical data concerning the location and severity of injury are presented in Table 6.

Table 6. Location and severity of overuse injuries.

Problem Location	(%)	Duration (Days) of Problem (%)		Extent of Training Volume Reduction (%)		Impact on Performance (%)		Extent of Pain Experience (%)	
Knee	26.3	1–3		No reduction		No effect	10.5	Minor	
		4–7	26.3	Minor	10.5	Minor	15.8	Moderate	21.0
		8–28		Moderate	10.5	Moderate		Major	5.3
		>28		Major	5.3	Major			
Hip	0.0	1–3		No reduction		No effect		Minor	
		4–7		Minor		Minor		Moderate	
		8–28		Moderate		Moderate		Major	
		>28		Major		Major			
Back	21.1	1–3	5.3	No reduction	10.5	No effect	5.3	Minor	
		4–7	10.5	Minor	5.3	Minor	10.5	Moderate	10.5
		8–28		Moderate		Moderate		Major	10.5
		>28	5.3	Major	5.3	Major	5.3		
Neck	10.5	1–3		No reduction	10.5	No effect	5.3	Minor	5.3
		4–7	5.3	Minor		Minor	5.3	Moderate	5.3
		8–28		Moderate		Moderate		Major	
		>28	5.3	Major		Major			
Other	5.3	1–3		No reduction		No effect		Minor	
		4–7		Minor		Minor		Moderate	
		8–28	5.3	Moderate		Moderate		Major	5.3
		>28		Major	5.3	Major	5.3		

(%)—percentage of valid observation.

3.4. Injury Prediction Value of FMS and YBT-LQ

Indicators of injury risk predictive value (sensitivity, specificity. and odds ratio) of the Functional Movement Screen and Y-balance tests are presented in Table 7.

Table 7. Indicators of injury risk predictive value for FMS and YBT-LQ.

	Sensitivity (95% CI)	Specificity (95% CI)	Odds Ratio (95% CI)
$FMS_{CS} \leq 14/21$	0.33 (0.04–0.78)	0.62 (0.32–0.86)	0.80 (0.10–6.10)
$YBT\text{-}LQ_{CS\text{-}L} \leq 94\%$	0.17 (0.04–0.64)	0.92 (0.64–1.00)	2.40 (0.12–46.39)
$YBT\text{-}LQ_{CS\text{-}R} \leq 94\%$	0.33 (0.04–0.78)	0.85 (0.55–0.98)	2.75 (0.28–26.61)
$YBT\text{-}LQ_{A\text{-}R\text{-}\Delta} \geq 4$ cm	0.17 (0.42–0.64)	0.92 (0.64–1.00)	2.40 (0.12–46.39)
$YBT\text{-}LQ_{PL\text{-}R\text{-}\Delta} \geq 4$ cm	0.67 (0.22–0.96)	0.69 (0.39–0.91)	4.50 (0.57–35.52)
$YBT\text{-}LQ_{PM\text{-}R\text{-}\Delta} \geq 4$ cm	0.33 (0.04–0.77)	0.46 (0.19–0.75)	0.43 (0.05–3.22)

FMS_{CS}—FMS composite score, $YBT\text{-}LQ_{CS\text{-}L,R}$—Lower Quarter Y-balance test composite score for left, right lower limb. $YBT\text{-}LQ_{A\text{-}R\text{-}\Delta,\ PL\text{-}R\text{-}\Delta,\ PM\text{-}R\text{-}\Delta}$—asymmetry in anterior, posterolateral, and posteromedial reach.

4. Discussion

The results of the current study showed that the values of the FMS composite score (FMS_{CS}) as well as those of the YBT-LQ test ($YBT\text{-}LQ_{CS}$) in youth road cyclists were similar to those observed by other authors in adolescent populations. However, the lowest scores were noted in hurdle step and in the trunk stability push-up for the FMS test, which may suggest the existence of core stability deficits. Moreover, despite good results of the FMS_{CS} and YBT-LQ tests, the evaluated adolescent cyclists suffered from overuse injuries during the 18-week period after conducting the assessment.

In our study, we noted a high percentage of 0 and 1 scores (in total, >30% of all cases) in two FMS component tests (hurdle step and trunk stability push-up) compared to other adolescent populations [62–64]. The hurdle step task is mainly used to assess unilateral hip extensor mobility and postural control [24]. Given the fact that for the evaluated cyclists, the results of YBT-LQ test did not indicate abnormalities in dynamic postural control, it can be suggested that cycling training may predispose to limitations in hip extension mobility. The trunk stability push-up task, in turn, is applied to evaluate core stability in the sagittal plane during symmetric upper limb movement [25] and upper body strength [65]. The alterations presented in this test may be attributed to poor stability of the trunk stabilisers [25]. Therefore, it may be probable that spending significant time in cycling position, which requires extreme trunk horizontal flattening and hip flexion achieved through excessive anterior pelvis tilt [16] in combination with a high level of physical effort [20], may overload tissues and lead to some deficits in the mobility (mainly in hip extension) and stability of the lumbo-pelvis complex and/or trunk. Furthermore, the potential reason for functional movement deficits observed in evaluated cyclists may be related to overall training specificity, which is mainly focused on endurance exercises and on general strength training [21–23]. However, specific functional exercises focused on lumbo-pelvic complex mobility and stability are very rarely performed by cyclists. Because cyclists spend most of their training time on a bike, much less time is devoted to functional exercises, which may negatively affect core musculature performance during stability tasks off a bike [23]. During the 18 weeks following evaluation, despite good results on the FMS_{CS} and YBT-LQ, more than 30% of studied group experienced some overuse injuries, mainly located in the knees and back. Therefore, we may suggest that those two parts of the FMS test (hurdle step and trunk stability push-up) may be indicative of weak points of the body in young cyclists that may be vulnerable to overload.

Abraham et al. [62] showed that the mean FMS_{CS} value in 10–17-year-old school students of both genders was 14.59 + 2.48. Similarly, Anderson et al. [66], in 31 healthy male secondary school athletes (age 16.0 + 1.1 years), reported a mean FMS_{CS} value of 15.3 + 2.1. Rannama et al. [67] and Rannama et al. [68] demonstrated FMS_{CS} values totalling 14.7 + 1.6 and 14.13 + 1.80 in male road cyclists (age 19.2 + 2.3 and 18.5 + 2.1 years, respectively). Only

Pfeifer et al. [69] reported a slightly lower mean and larger standard deviation of FMS_{CS}, that is, 12.62 + 3.06 (mode 14), in 63 male high-school students (age: 15.87 + 1.44 years). These FMS_{CS} values are similar to those obtained in our study (median: 15, 1st-3rd quartiles: 13–17). However, we should be careful with the interpretation of the FMS_{CS} result, because it is a combination of multiple subtests used to assess different movement qualities (i.e., mobility, strength, balance, etc.) in different body regions. Moreover, the weaknesses of this test are the task-specific criteria and high inter-individual variability in movement coordination and control, whereby a score of 2 points for a given test can be obtained in several different ways. Although FMS_{CS} may be similar between the evaluated athletes, these scores could have been obtained with different individual movement patterns [28,70].

The low sensitivity (SP) 0.33 (95% CI 0.04–0.78), specificity (SE) 0.62 (95% CI: 0.32–0.86), and odds ratio (OR) 0.80 (95% CI: 0.10–6.10) observed in our study indicated poor ability of $FMS_{CS} < 14/21$ to predict injury risk in youth road cyclists. For other studies in physically active populations, equivocal results were provided. Some authors underlined that poor performance on the FMS_{CS} may reflect a history of injury rather than predict future injury risk [70]. In the majority of meta-analysis reviews, the strength of association between $FMS_{CS} \leq 14/21$ and subsequent injury is not supported, nor is its use as an injury prediction tool [71–74]. Dorrel et al. [71] showed an SE of 0.24 (95% CI: 0.15–0.36) and SP 0.85 (95% CI: 0.77–0.91) in active adult populations. Moore et al. [72], in junior athletes, demonstrated an SE totalling 0.50 (95% CI: 0.43–0.57), SP of 0.59 (95% CI: 0.44–0.72), and OR equalling 1.16 (95% CI: 0.72–1.87), and showed that the prediction value of FMS_{CS} $< 14/21$, which may vary depending on population, injury mechanism, and injury definition. In male military personnel, Moran et al. [73] reported 'strong' evidence that the strength of association between composite score (cut-point $\leq 14/21$) and subsequent injury was 'small'. Beardsley et al. [74] even suggested that the probable predictive criterion-referenced validity value of the $FMS_{CS} \leq 14/21$ may be only marginally better than a coin toss for identifying individuals who are genuinely at risk of injury. By contrast, in a review by Bonazza et al. [75] including nine prospective cohort studies, it was reported that participants (athlete, fire-fighter, and military populations) who scored ≤ 14 on the FMS have greater than two-fold—OR of 2.74 (95% CI: 1.70–4.43)—the odds of sustaining a musculoskeletal injury than those with scores > 14 (but the authors of this review ignored heterogeneity in the study population type, follow-up time, and injury definition [72]). Low injury risk predictive value of the FMS test may be due to its low construct validity. The FMS test allows the identification of compensatory, painful, and asymmetric movement patterns in tasks, which are often different from those performed in specified sports disciplines. Thus, it is equivocal how the identification of such compensatory movement patterns may be significantly linked to the prediction of sport-related injury. Furthermore, it is also worth highlighting that when using FMS_{CS}, the cut-off value should be adjusted to subject age, gender, experience, and level of competition. Therefore, FMS_{CS} should be used with caution as a criterion differentiating athletes with high and low risk of injury.

The YBT-LQ composite score ($YBT\text{-}LQ_{CS}$) reported in our study did not differ from values observed in adolescent athletes by other authors [76–78]. Schwiertz et al. [76], in male volunteers aged 14–15 years, observed a 97.0% level of $YBT\text{-}LQ_{CS}$ composition score for the right leg and 98.1% for the left one. The higher values were reported in the 16–17 age group: 101.5%, and 102.8% for the right and left sides, respectively. Similarly, Alhusaini et al. [77], in healthy male children aged 12 to 15 years, demonstrated 94.13 + 8.83% for the right side and 93.68 + 8.79% for the left side. Such a value of YBT composition score (93.3 + 9.6%) was also noted by O'Connor et al. [78] in adolescent Gaelic footballers and hurlers. In our study, no asymmetry in composite score or reach distance was observed, suggesting that cycling training probably did not adversely affect the dynamic postural control of the young cyclists under evaluation.

In our study, performance on the YBT-LQ test (composite score < 94%, and reach distance asymmetry >4 cm) showed low injury prediction value in the evaluated cyclists. Moreover, in the literature, ambiguous observations have been noted. Butler et al. [49]

reported an odds ratio of 3.5 (95% CI 2.4–5.3) when using a composite cut-off of 89.6% in football players. Wright et al. [46] and Brumitt et al. [45] utilised different composite cut-offs for athletic teams, ranging between 89 and 94%, all of which yielded non-significant likelihood ratios (ranges: 0.55–1.32 and 0.50–1.70, respectively). Smith et al. [43] utilised 4-cm anterior reach distance asymmetry and found a relationship with future injury risk, reporting an odds ratio of 2.20 (95% CI 1.09–4.46). Vaulerin et al. [79] found that an asymmetry of >2 cm was predictive of ankle sprains. Šiupšinskas et al. [80] reported only limb difference scores and did not find an association with injury in elite female basketball players. Gonell et al. [81] indicated an odds ratio of 3.86 (95% CI 1.46–10.95) for male soccer players with a posteromedial asymmetry of 4 cm or greater. Lehr et al. [82] used population specific cut-points for various sports. The researchers found that injury predictive values of the YBT-LQ were increased when multiple risk factors were combined. The authors applied age, sex, and sport-specific risk cut-points to place athletes in risk categories. These cut points were based on previously published injury prediction studies and normative databases. Thus, it seems important to include age, sex, and sport cut-points for injury risk identification.

The limitation of this study is the fact that in the research, a homogeneous (in terms of age and sex) and relatively small group of road cyclists was included; thus, the results cannot be generalised to a broader population. Moreover, the study population included athletes with a wide range training experience, which should be taken into account, while training experience was previously reported as injury factor [83].

5. Conclusions

The most important information from this study is that youth road cyclists may have functional deficits within the lumbo-pelvic-hip complex and the trunk. Moreover, neither the FMS test nor the YBT-LQ test are not recommended for injury risk screening in adolescent cyclists. Future research is needed to develop specific tests for cyclists and specific cut-points for FMS and YBT-LQ composite scores to more accurately determine future injury risk.

Author Contributions: Conceptualisation, B.Z. and A.M.; methodology, B.Z. and A.M.; software, B.Z. and P.K.G.; validation, B.Z., A.M. and T.A.; formal analysis, B.Z., A.M. and T.A.; investigation, B.Z. and A.M.; resources, B.Z. and P.K.G.; data curation, B.Z. and T.A.; writing—original draft preparation, B.Z.; writing—review and editing, B.Z. and A.M.; visualisation, B.Z. and P.K.G.; supervision, B.Z., A.M. and T.A.; project administration, B.Z.; funding acquisition, B.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This study was performed within the framework of the programme provided by the Minister of Science and Higher Education under the name 'Regional Initiative for Perfection' within the years 2019–2022, project No. 022/RID/2018/19, supported by the National Science Centre in Poland.

Institutional Review Board Statement: All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. Consent to perform testing was provided by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 249/KBL/OIL/2021). Written informed consent to participate in this study was provided by the participants' legal guardians/next of kin.

Informed Consent Statement: Written informed consent to participate in this study was provided by the participants' legal guardians/next of kin.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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7. Publikacja B

Tytuł: Effects of Anaerobic Fatigue Induced by Sport-Specific Exercise on Postural Control in Highly-Trained Adolescent Road Cyclists.

Cel pracy: Określenie efektów oddziaływania zmęczenia beztlenowego wywołanego wysiłkiem rowerowym na stabilność posturalną u dorastających kolarzy szosowych.

Materiał i metody: W badaniu wzięło udział 23 kolarzy szosowych w wieku 15-17 lat. Kontrolę równowagi oceniono przed i 3 minuty po maksymalnym 30-sekundowym wysiłku rowerowym za pomocą platformy podobarograficznej, która rejestrowała ścieżkę środka nacisku stóp na podłoże (CoP) na dwuwymiarowej przestrzeni.

Wyniki: Zmęczenie beztlenowe wywołało u kolarzy statystycznie istotny wzrost pola powierzchni elipsy oraz zakresu wychyleń CoP w płaszczyźnie strzałkowej i czołowej, zarówno przy otwartych, jak i zamkniętych oczach. Ponadto, odnotowano statystycznie istotny spadek częstotliwości wychyleń CoP w obu tych warunkach. U zmęczonych zawodników zanotowano również istotny statystycznie wzrost stosunku zakresów wychyleń CoP w płaszczyźnie strzałkowej do czołowej, co dotyczy pomiarów wykonanych przy zamkniętych oczach.

Wnioski: Zmęczenie wywołane wysiłkiem beztlenowym zakłóca działanie systemu kontroli równowagi u dorastających kolarzy szosowych, co może przyczyniać się do zwiększonego ryzyka upadków podczas zawodów i treningów. Obserwacja ta powinna być użyteczna dla organizatorów wyścigów kolarskich, zwłaszcza w kontekście zabezpieczania kluczowych sektorów trasy, takich jak technicznie wymagające odcinki, gdzie kolarze mogą dodatkowo doświadczać zmęczenia beztlenowego, np. na krętych zjazdach z przełęczy bezpośrednio po rywalizacji o premię górską. Ponadto, wyniki badania powinny zachęcić trenerów do włączania ćwiczeń ukierunkowanych na kształtowanie kontroli równowagi w warunkach zmęczenia beztlenowego do programów treningowych dojrzewających kolarzy szosowych.

Ograniczenia: Do ograniczeń badania zaliczyć należy: (i) brak pomiaru wychwiań CoP bezpośrednio po wysiłku; (ii) brak rejestracji wskaźników restytucji powysiłkowej; (iii) brak grupy kontrolnej, np. amatorskich sportowców lub reprezentujących inne dyscypliny sportowe; (iv) przeprowadzenie badania na homogenicznej pod względem płci i wieku populacji.

applied sciences

MDPI

Communication

Effects of Anaerobic Fatigue Induced by Sport-Specific Exercise on Postural Control in Highly-Trained Adolescent Road Cyclists

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Abstract: The aim of this study was to evaluate whether and how anaerobic fatigue induced by sport-specific exercise affects the postural control of highly-trained adolescent road cyclists. Twenty-three male athletes, aged 15–18 years, were included in the study. Postural control was assessed using the pedobarographic platform (bipedal upright stance, sequentially, with eyes open (EO) and closed (EC) for 60 s each, with a 30 s interval), before and 3 min after a 30 s all-out effort performed on the ergometer. The results showed significant increases in the 95%-confidence ellipse area (p-value 0.000 and 0.001 for EO and EC, respectively), as well as centre-of-pressure (CoP) range displacement in the anteroposterior (p-value 0.000 for both EO and EC) and mediolateral (p-value 0.011 and 0.001 for EO and EC, respectively) planes. In addition, a significant decrease in CoP mean sway frequency was observed (p-value 0.000 and 0.001 for EO and EC, respectively), but no changes were noted in CoP mean velocity (p-value 0.316 and 0.670 for EO and EC, respectively). In our study, it has been indicated that anaerobic fatigue induced by sport-specific exercise deteriorates postural control in adolescent cyclists. Moreover, cycling training may affect the quality of postural corrective reactions occurring in response to anaerobic fatigue.

Keywords: postural control; body sway; anaerobic fatigue; cyclists; sport-specific exercise

Citation: Zając, B.; Mika, A.; Gaj, P.K.; Ambroży, T. Effects of Anaerobic Fatigue Induced by Sport-Specific Exercise on Postural Control in Highly-Trained Adolescent Road Cyclists. *Appl. Sci.* **2023**, *13*, 1697. https://doi.org/10.3390/app13031697

Academic Editor: Mickey Scheinowitz

Received: 5 January 2023
Revised: 20 January 2023
Accepted: 27 January 2023
Published: 29 January 2023

1. Introduction

Road cycling is one of the most extreme endurance sports. Professional road cyclists typically train ~20 h per week and cover ~600 km a week [1]. The longest 1-day race in men's cycling can be up to 300 km while the longest multiple-stage races can last up to 21 days. The most demanding competitions are so-called grand tours in which athletes compete for 21 days (>3000 km) with only 2 days dedicated to rest in between [2]. Interestingly, in the course of such a long-lasting competition, work intensity may by very high. The percentage of the total flat race time spent by professional cyclists at an intensity below 70%, between 70 and 90%, and above 90% of maximal oxygen uptake averages approximately 70, 25, and 5%, respectively [2]. During races, ~20–70 accelerations take place, exceeding maximal aerobic power [3]. Moreover, male elite cyclists may generate power exceeding 1200 W (17 W $\times$ kg^{-1}) during final sprints [4]. In addition, data have indicated that the younger category of competition may be even more intense than the elite in terms of internal intensity [5]. Apart from huge training and race loads, road cycling is also a very demanding sport on the postural control system due to the presence of various external destabilising factors related to the course of training or competition with which the cyclist's body must cope in order to avoid falls, for example, winding roads of various pavements [6], high speed [7], a large number of rivals, and variable weather conditions [2].

The human body in the upright bipedal standing position is constantly swaying due to the inability of the neuromuscular system to maintain constant muscular tension [8] as well as the presence of physiological destabilising factors such as body liquid movements, heart work, and respiratory muscular contraction [9,10]. Despite this, the human body is able to maintain a vertical projection of the centre of gravity within the base of support due to the operation of the postural control system. The quality of postural control may be quantified by registering the trajectory of the centre of pressure (CoP) using force platforms, which track the point of application regarding ground reaction forces resultant under the feet present during upright standing [11]. The resulting signal, called the stabilogram, provides various parameters describing postural control quality such as positional parameters (e.g., 95%-confidence ellipse area [EA], distance between extreme points of the stabilogram (range) in anteroposterior [AP_R] and mediolateral [ML_R] planes, as well as AP_R/ML_R ratio), dynamic parameters (e.g., CoP mean velocity [MV] calculated as path length divided by time of measurement), and frequency parameters (e.g., CoP mean frequency [MV] defined as the rotational frequency, considering the total CoP length as a trajectory around a circle with a radius equal to the mean distance) [11].

Generally, exercises that solicit a large part of body musculature (general exercise)—for instance, cycling—cause the aggravation of postural sway due to increased cardiac and breathing rhythm as well as intensified body liquid flow [12]. Moreover, general exercise generates fatigue which affects postural control by decreasing the quality of input sensory information and its integration, as well as output motor command efficiency. The crucial exercise parameters influencing the size of postural sway aggravation and postural control deterioration are intensity and duration. A large acid–base imbalance due to the dissociation of lactic acid produced into lactate and hydrogen is typical for high-intensity, short-term exercises. In contrast, low-intensity, long-term exercise may cause elevated body temperature, dehydration, muscle damage, and/or the depletion of glycogen storage [13]. In addition, the size of postural control deterioration may depend on exercise type, intensity of proprioceptive stimulation, forms of muscle contraction, and the activation of muscle fibres [14].

There are many reports in which it is suggested that fatigue deteriorates postural control. Some authors studied in different populations the influence of various fatiguing protocols in terms of energetic background (aerobic [15,16] or anaerobic [17–21]), and exercise type (general [16,22,23], or local [24–26]) in different populations. However, in only a number of works are the effects of sport-specific fatiguing protocols shown with regard to athletes' postural control [13]. To the best of our knowledge, there are no studies in which the impact would be evaluated of anaerobic fatigue induced by sport-specific exercise on adolescent road cyclists' postural control. These athletes are exposed to both large amounts of fatigue of various etiologies (on this basis, of anaerobic background) and various external factors hindering postural control. We hypothesize that the combination of these factors may induce changes in the operation of postural control in response to anaerobic fatigue. Therefore, the aim of this study was to evaluate whether and how anaerobic fatigue induced by sport-specific exercise has an impact on the efficiency of postural control in highly-trained adolescent road cyclists.

2. Materials and Methods

2.1. Study Design

Postural control was assessed with eyes open and closed before and 3 min after an effort carried out on a cycle ergometer. We decided to perform the second assessment after 3 min to reduce aggravation of body sway related to post-effort hyperventilation and tachycardia. Moreover, the somatic measurements and data on the training experience were collected. The course of the study was presented in Figure 1. All measurements were performed by experienced researchers between 10:00 a.m. and 4:00 p.m. at an ambient temperature of 20 ± 1 °C and relative humidity of 40 ± 5%. Participants were asked to remain well-hydrated, to refrain from consuming alcohol or any stimulants for at least 24 h before testing, and not to engage in strenuous exercise at least 48 h prior to testing. Each participant was familiarised with the measurement procedure. The study was approved by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 249/KBL/OIL/2021). All procedures were carried out in accordance with Helsinki Declaration.

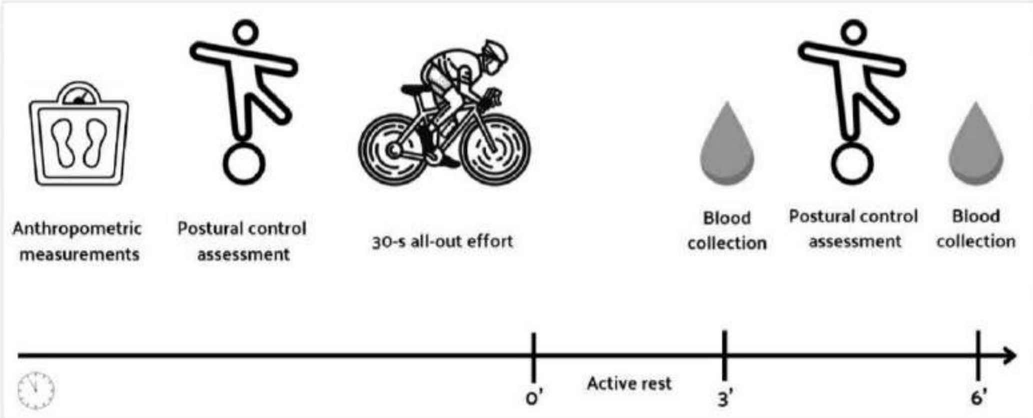

Figure 1. The course of the study.

2.2. *Participants*

The study evaluated 23 male cyclists recruited from among students of the Sport Championship School in Cycling in Poland. Sample size was calculated using G*Power 3.1.9.6 software (input parameters: two tails, effect size 0.6, α 0.05, power 0.7). Main characteristics of the cyclists are showed in Table 1. The inclusion criteria were: (i) progression of biological development—minimum 3rd pubic hair stage on Tanner's Scale [27]; (ii) "highly-trained/national" sports level according to [28] participant classification framework for research in sports sciences; (iii) having a current certificate from a sports medicine doctor regarding the ability to practice road cycling. The exclusion criteria were: (i) age above 18 years, (ii) postural control disorders identified in the past, (iii) health condition making it impossible to perform the tests. The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Table 1. Main characteristics of the studied cyclists.

	Median (Q_1–Q_3)	Minimum	Maximum	CQV (%)
Age [year]	16 (15–17)	15	17	6.3
TE [year]	5 (3–6)	1	8	30.0
BH [cm]	178.5 (174.0–180.5)	167.5	192.0	1.8
BW [kg]	63.2 (60.1–67.6)	52.6	82.2	5.9
BMI [kg $\times$ m^{-2}]	20.3 (19.2–21.0)	17.8	25.2	4.5
LBM [kg]	53.4 (51.0–57.3)	43.9	67.1	5.9
BF [kg]	9.8 (8.7–12.2)	6.5	15.1	17.9
BF [%]	15.5 (14.5–17.9)	11.1	19.7	11.0

Q_1–Q_3—1st and 3rd quartiles; CQV—coefficient of quartile variation; TE—training experience; BH—body height; BW—body weight; BMI—body mass index; LBM—lean body mass; BF—body fat.

2.3. *Somatic Assessment*

Body height (BH) was determined with stadiometer seca 213 (seca gmbh & co., kg, Deutschland) with 1mm accuracy. Body weight (BW), body fat (BF), and lean body mass (LBM) were determined with multi-frequency (5 kHz/50 kHz/250 kHz) MC 780 MA device (Tanita, Japan), using the bioelectrical impedance method [29]. At baseline, feet and hands of the athletes and electrodes were sanitized and cleaned. Body mass index (BMI) was calculated in following manner: BW in kilograms ÷ BH in metres squared.

2.4. Postural Control Assessment

The evaluation of postural control was performed using the FreeMED Posture Base pedobarographic platform (Sensor Medical, Italy) with a sampling frequency of 400 Hz, recording movement of CoP in 2-dimensional space. The platform was supported by FreeStep v.1.3.34 software using a low-pass filter to remove any artefacts below 10 Hz. Before initiating measurements, the subject was familiarised with the measuring equipment and test procedure. The measurement was carried out in a quiet room, barefoot, in a standing position, with feet parallel to the width of the pelvis and upper limbs hanging freely along the body [30]. During the measurement, the subject stood on the platform motionless, sequentially, eyes open and closed for 60 s each, with a 30 s interval [30]. The following variables of postural control were analysed: 95%-confidence ellipse area (EA), CoP range displacement in the anteroposterior (AP_R) and mediolateral (ML_R) planes, AP_R/ML_R ratio, CoP mean velocity (MV), and CoP median frequency (MF).

2.5. Fatiguing Protocol and Biochemical Analysis

The effort was performed on the Cyclus 2 ergometer (RBM elektronik-automation GmbH, Germany) with the athlete's own bike installed (the same on which he trained and competed in the race). The ergometer was calibrated in accordance with the manufacturer's recommendations. Before the effort, the participant performed a 5 min warm-up with a load totalling 1.2% of body mass. The pedalling rate during the warm-up equalled 90 rpm. During the final 3–5 s of the second and fourth minutes of the warm-up, the athletes carried out maximal accelerations. Two minutes after the warm-up, the maximal 30 s all-out effort with stationary start was performed. The resistance applied during the test was set at 10% body weight [31]. At the "go" command, the task of the subject was to obtain the highest-possible pedalling rate as quickly as possible and then maintain it in a seated position until the end of the effort (with strong verbal encouragement). During the effort, peak power, time to obtain peak power, mean power, and minimal power were registered. Fatigue index was calculated in the following manner: ((peak power − minimal power) ÷ (peak power)) × 100% [32]. After effort, cyclists were pedalling 2 min without load with frequency 50–60 rpm. During the 3rd and 6th minutes following the effort, 20 μL of blood were collected by medical staff from the fingertip for measurement of blood lactate concentration (BL) with the Super GL2 device (Dr. Müller Gerätebau GmbH, Freital, Germany), employing the enzymatic amperometric electrochemical technique. The analyser was calibrated before each series of obtaining samples.

2.6. Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 26. Changes in postural control variables were evaluated with the paired-sample *t*-test or the Wilcoxon signed-rank test, depending on consistency of the variables' distribution with normal distribution, which was examined using Shapiro–Wilk test. Level of statistical significance was set at <0.05. The effect size (ES) for the paired *t*-test samples was calculated via dividing the mean difference by the standard deviation of the difference, while for the Wilcoxon signed-rank test, it was calculated through dividing the z-value by the square root of the observation number [33]. ES was interpreted as small (<0.3), medium (0.3–0.5), or large (>0.5) [33].

3. Results

3.1. Somatic Indices

Table 1 shows the main characteristics of the study's cyclists.

3.2. Fatiguing Protocol and Biochemical Response

The kinetic values obtained during the effort as well as BL concentrations from the third and sixth minutes after the effort are presented in Table 2.

Table 2. Kinetic data collected during the effort and BL concentration after its completion.

	Median (Q_1–Q_3)	Minimum	Maximum	CQV (%)
Peak power [W]	910 (851–983)	710	1232	7.3
Peak power [W × kg^{-1}]	14.2 (13.4–15.6)	13.4	15.6	7.7
Time to peak power [s]	3.30 (2.50–3.80)	1.00	7.40	19.7
Mean power [W]	716 (671–774)	553	894	7.1
Mean power [W × kg^{-1}]	11.4 (10.6–11.5)	10.3	12.6	4.1
Minimal power [W]	535 (466–579)	419	658	10.8
Minimal power [W × kg^{-1}]	8.2 (7.8–8.8)	6.3	8.8	6.0
Fatigue index [%]	41.2 (37.6–46.8)	31.0	56.0	10.9
Blood lactate 3′ [mmol × L^{-1}]	12.9 (12.0–14.0)	9.8	16.0	7.7
Blood lactate 6′ [mmol × L^{-1}]	11.9 (10.6–13.3)	8.6	15.1	11.3

Q_1–Q_3—1st and 3rd quartiles; CQV—coefficient of quartile variation.

3.3. Postural Control Indices before and after Effort (Eyes Open)

After the effort, significant increases were registered in EA (large ES), AP_R (large ES), and ML_R (small ES), as well as a decrease in MF (large ES). AP_R/ML_R ratio and MV did not change significantly (small effect size) (Table 3).

Table 3. Postural control indices before and after the effort (eyes open).

	Before	After	Difference (%)	*p*-Value	ES
EA [mm^2]	92.2 (56.6–125.6) CQV: 37.8%	250 (151–670) CQV: 63.2%	231.2 (79.2–564.1)	0.000 *	0.59
AP_R [mm]	12.0 (10.6–16.1) CQV: 20.6%	25.7 (18.7–45.3) CQV: 41.6%	110.9 (24.7–323.1)	0.000 *	0.93
ML_R [mm]	10.8 (8.6–14.3) CQV: 24.9%	17.8 (10.9–25.6) CQV: 40.1%	44.3 (−0.82–188.7)	0.011 *	0.28
AP_R/ML_R	1.07 (0.82–1.57) CQV: 31.4%	1.42 (1.12–1.96) CQV: 27.3%	12.3 (−11.7–114.5)	0.136	0.10
MV [mm × s^{-1}]	10.7 (9.1–12.3) CQV: 15.0%	10.6 (10.1–11.7) CQV: 7.3%	1.8 (−7.2–37.7)	0.315	0.04
MF [Hz]	1.11 (0.95–1.26) CQV: 14.0%	0.80 (0.72–0.87) CQV: 9.4%	−21.3 (−33.0 to −10.9)	0.000 *	1.09

Data are expressed as median (with 1st and 3rd quartiles); EA—95%-confidence ellipse area; AP_R, ML_R—CoP range displacement in the AP and ML planes; AP_R/ML_R—ratio of AP_R and ML_R; MV—CoP mean velocity; MF—CoP mean frequency; *p*-value—probability of Type I error; * statistically significant difference; ES—effect size; CQV—coefficient of quartile variation.

3.4. Postural Control Indices before and after Effort (Eyes Closed)

After the effort, significant increases were registered in EA (medium ES), AP_R, and ML_R (in both cases, large ES), with a relatively greater increase in the AP_R, as well as decrease in MF (medium ES). MV did not change significantly (small ES) (Table 4).

Table 4. Postural control indices before and after the effort (eyes closed).

	Before	After	Difference (%)	*p*-Value	ES
EA [mm^2]	90.8 (42.9–291.3) CQV: 74.3%	265 (158–761) CQV: 65.6%	181.7 (−12.5–657.5)	0.001 *	0.49
AP_R [mm]	10.2 (8.4–21.2) CQV: 43.2%	30.2 (21.0–40.8) CQV: 32.0%	141.3 (38.7–276.2)	0.000 *	1.08
ML_R [mm]	12.3 (9.3–15.5) CQV: 25.0%	17.0 (12.6–29.5) CQV: 40.1%	77.7 (1.8–114.0)	0.001 *	0.82
AP_R/ML_R	1.09 (0.70–1.5) CQV: 36.4%	1.66 (1.11–2.16) CQV: 32.1%	46.6 (−11.8–141.1)	0.026 *	0.50
MV [mm × s^{-1}]	11.9 (9.6–13.5) CQV: 16.9%	11.6 (10.3–12.4) CQV: 9.3%	2.3 (−10.0–25.4)	0.670	0.01
MF [Hz]	1.14 (1.04–1.26) CQV: 9.6%	0.87 (0.78–0.96) CQV: 10.3%	−21.1(−29.0 to −9.3)	0.000 *	0.80

Data are expressed as median (with 1st and 3rd quartiles); EA—95%-confidence ellipse area; AP_R, ML_R—CoP range displacement in the AP and ML plane; AP_R/ML_R—ratio of AP_R and ML_R; MV—CoP mean velocity; MF—CoP mean frequency; *p*-value—probability of Type I error; * statistically significant difference; ES—effect size; CQV—coefficient of quartile variation.

4. Discussion

The main finding of this study is that anaerobic fatigue induced by sport-specific exercise deteriorates postural control in highly-trained adolescent road cyclists. What is also of significance in this research is that deterioration of postural control was visible as an increase in the positional parameters of body sway (EA, AP_R, and ML_R) as well as a decrease in MF, but not a change in MV. To best of our knowledge, this is the first study in which the effect was examined of anaerobic fatigue induced by sport-specific exercise on postural control in adolescent road cyclists.

In our study, anaerobic fatigue induced a significant increase in the majority of positional body sway parameters (i.e., EA, AP_R, and ML_R), both with eyes open and closed. It was only the AP_R/ML_R ratio with eyes open that did not increase substantially after the effort. Similar changes were also observed by other authors when anaerobic fatiguing protocols were used: the Wingate Anaerobic test (young judokas [17]; 13-year-old alpine skiers [18]); repeated sprint ability test among soccer players [19]; U19 basketball players [20]); and the Bosco protocol (recreationally trained volunteers [21]). All these protocols linked (beyond the anaerobic background) the involvement of a large number of muscles (general exercise type) mainly in the lower extremities. Therefore, the probable explanation for postural control disturbances may be that high-intensity general exercise such as cycling, running, or jumping deteriorates the quality of sensory information (proprioceptive, visual, vestibular, and plantar cutaneous inputs) and/or their integration, while potentially decreasing the efficacy of the muscular system [34–36]. Metabolic products diminish the facilitation of muscle spindle afferents and thus reduce the efficiency of the myotatic loop during postural regulation. Windhorst [37] specifies that the action of the chemosensitive group III and IV muscle afferents reduces the motor resolution in response to any input, which might lead to less efficient control and reduced motor output accuracy. Another explanation may be the decrease of lower limb muscle strength (the median fatigue index registered in our study was 41.2%). Dickin and Doan [38] and Harkins et al. [39] reported that the decrease in the strength of the ankle or knee musculature as a result of fatigue significantly disturbed postural control, and manifested in increased EA, AP_R, as well as ML_R. Another important aspect which should be addressed while explaining changes in postural control induced by cycling exercises is neck musculature fatigue [25,40]. The cycling position, which require extreme trunk horizontal flattening [41], predisposes one to fatigue in the neck muscles [42]. It has been reported that nociceptive sensorial inputs induced by fatigue of the neck muscles deteriorate the ability to correctly perceive verticality and, moreover, the fatigue degrades spatial body orientation, influencing postural balance [25,43,44]. Postural control disturbances may also be the effect of a large acid–base imbalance [45]. The applied effort induced large increases in BL concentration among the studied athletes (the median BL concentration was 12.9 and 11.9 mmol $\times$ L^{-1} during the third and sixth minutes, respectively, following the effort).

Interestingly, in our study, MV did not significantly change after the effort, while MF decreased substantially. Other authors using anaerobic exercise to induce fatigue obtained different results, i.e., increased MV [17–20], and no changes in MF [17,20]. We have suggested that divergent results may be caused by the different time intervals between the end of the effort and body sway measurements. In our research, posturography was performed between the third and sixth minutes following the fatiguing protocol, while all the cited authors, excluding Jastrzębska [18], carried out measurements immediately after the effort. The protocol used in our study reduced the aggravation of body sway arising from post-exercise tachycardia, hyperventilation, as well as body liquid movement. Another aspect to be considered in trying to explain divergent results is that the anaerobic fatigue in our study was induced via sport-specific exercise, while other authors used non-specific exercise. The observed postural control reaction may, therefore, be characteristic only of road cyclists in whom permanent large exposure to fatigue of various etiologies, in combination with destabilising factors, potentially causing an adaptation in postural control corrective responses. The significant MF decrease noted in our study could also suggest that road cycling training modifies the implemented corrective strategy. Our suggestion is supported by the work of Harkins et al. [39] who observed that in young subjects, balance strategies may change—from the ankle to the hip strategy—when the fatigue is localised at the ankle musculature level. Due to the fact that MF is part of the ankle corrective strategy, it would be probable that a high level of calf muscle fatigue caused by cycling exercise may result in a shift to the hip corrective strategy as that is superior in postural control regulation.

This study showed that short-term, high intensity effort (such as acceleration during a road race) inducing anaerobic fatigue deteriorates postural control in adolescent cyclists, and therefore may increase the risk of falls during competition or training. Decock et al. [46] have reported that 10–13% of all competing Flemish youth riders experience falls during a race and each such incident results in some injuries. Moreover, De Bernardo et al. [47] have suggested that falls cause almost half of the injuries among professional road cyclists. We think that the situations in which anaerobic fatigue is combined with technically difficult and unsafe sectors of the competition/training may be especially dangerous for athletes' health, e.g., a downhill ride from a pass with high speed after a mountain premium sprint. Due to this, we recommend implementing sport-specific balance exercises carried out in anaerobic fatigue conditions in the training programmes of cyclists. Meta-analysis performed by Brachman et al. showed that such exercises have a positive effect on balance performance; therefore, their implementation may reduce the risk of falls and the traumatic injuries induced by them.

The limitations of this study included: (i) the lack of additional measurements regarding body sway immediately after the effort; (ii) the lack of cardiopulmonary parameter registration during the restitution period, showing fatigue status; (iii) potential visual or auditory interference due to not wearing ear muffs and eye masks during postural control assessment with eyes closed; (iv) the lack of a control group, e.g., amateur athletes or those representing different sports disciplines; (v) performing research on a homogeneous (in terms of sex and age) population; thus, the results cannot be generalised to a broader population.

5. Conclusions

In our study, it has been indicated that anaerobic fatigue induced by sport-specific exercise deteriorates postural control in adolescent road cyclists. Moreover, based on the results of our research, we suggest that cycling training, due to its specificity, may affect the quality of postural corrective reactions occurring in response to anaerobic fatigue, which may differ from those occurring in athletes performing other disciplines or in non-training people. Therefore, we recommend implementing balance exercises carried out in anaerobic fatigue conditions in the training programmes of cyclists, because they may result in positive effects in terms of fall prevention. Future studies should consider evaluating the effects of fatigue induced by protocols combining long-duration, low-intensity efforts, and short-duration, high-intensity efforts on postural control. In addition, in the future, a greater number of measurements should be taken into account (with regard to body sway) after the applied fatiguing protocol in order to determine changes of postural control during the restitution period.

Author Contributions: Conceptualization, A.M. and B.Z.; methodology, A.M. and B.Z.; software, B.Z. and P.K.G.; validation, A.M., B.Z. and T.A.; formal analysis, A.M., B.Z. and T.A.; investigation, A.M. and B.Z; resources, B.Z. and P.K.G.; data curation, B.Z. and T.A.; writing—original draft, B.Z.; writing—review and editing, A.M. and B.Z.; visualisation, B.Z. and P.K.G.; supervision, A.M. and B.Z.; project administration, B.Z.; funding acquisition, B.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This study was performed within the framework of the programme of the Minister of Science and Higher Education under the name "Regional Initiative for Perfection" within the years 2019–2022, project No. 022/RID/2018/19, supported by the National Science Centre in Poland.

Institutional Review Board Statement: The study project was approved by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 249/KBL/OIL/2021). All procedures were carried out in accordance with the Helsinki Declaration.

Informed Consent Statement: Written informed consent was collected from participants and their legal guardians.

Data Availability Statement: All data are available from the corresponding author on request.

Conflicts of Interest: The authors declare no conflict of interest.

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8. Publikacja C

Tytuł: Analysis of training loads in polish adolescent road cyclists in the preparatory period and their effects on physical fitness.

Cel pracy: Analiza wielkości i struktury obciążeń treningowych realizowanych przez polskich kolarzy szosowych o wysokim poziomie sportowym podczas 18-tygodniowego okresu przygotowawczego oraz ocena ich wpływu na wydolność fizyczną.

Materiał i metody: W badaniu wzięło udział 23 kolarzy szosowych w wieku od 15 do 17 lat, z których 16 ukończyło wszystkie etapy projektu. Ocenę wydolności tlenowej wykonano za pomocą testu progresywnego do odmowy, w trakcie którego mierzono przede wszystkim wskaźniki funkcji układu oddechowego i krążeniowego. Ocenę wydolności beztlenowej przeprowadzono przy użyciu zmodyfikowanego testu Wingate. Obciążenia treningowe tj. objętość, intensywność i rodzaj aplikowanych ćwiczeń rejestrowano przy użyciu sport-testera, a także dzienniczka treningowego pełniącego rolę uzupełniającą.

Wyniki: Obciążenia treningowe realizowane przez kolarzy charakteryzowały się niską objętością (przeciętnie ~7.7 h × $tydz.^{-1}$) i niespolaryzowanym (średni indeks polaryzacji wyniósł 0.15) piramidalnym ($strefa^1$ ~68%; $strefa^2$ ~26%; $strefa^3$ ~1% całkowitej objętości treningowej) rozkładem intensywności. Trening ukierunkowany na kształtowanie możliwości wytrzymałościowych i siłowych stanowił kolejno 95 i 5% całkowitej objętości treningowej. Zastosowany model treningowy nie przyniósł znaczącej poprawy wydolności tlenowej i beztlenowej.

Wnioski: Mając na uwadze, że zastosowany model przygotowań okazał się nieskuteczny z perspektywy podnoszenia wydolności fizycznej, racjonalnym rozwiązaniem w kolejnych iteracjach procesu przygotowawczego, wydaje się być zastosowanie większej objętości treningowej, przy zachowaniu struktury intensywności, lub zwiększenie ilości pracy o wysokiej intensywności (tzn. powyżej drugiego progu metabolicznego), przy utrzymaniu całkowitej objętości.

Ograniczenia: Do ograniczeń tego badania zaliczyć należy: (i) niewielką liczebność próby, (ii) brak grupy kontrolnej, (iii) wykorzystanie do rejestracji obciążeń treningowych metody niedoszacowującej objętości pracy o wysokiej intensywności, (iv) brak rejestracji szczegółowych danych na temat aplikowanego treningu oporowego i stosowanej suplementacji.

JKES
Journal of Kinesiology and Exercise Sciences

ISSN: 2956-4581
Journal of Kinesiology and Exercise Sciences

104 (33): 00-00, 2023
ORIGINAL RESEARCH

(0.0) DOI: 10.5604/01.3001.0053.9657

ANALYSIS OF TRAINING LOADS IN POLISH ADOLESCENT ROAD CYCLISTS IN THE PREPARATORY PERIOD AND THEIR EFFECTS ON PHYSICAL FITNESS

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

Received: 13.07.2023
Revised: 26.07.2023
Accepted: 09.10.2023
Published: 30.10.2023

Keywords: training loads; road cycling; aerobic fitness; anaerobic fitness

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Abstract:

Background: Road cycling is one of the most extreme endurance sports. Professional road cyclists typically train ~20 hours per week and cover ~600 km a week. The longest 1-day race in men's cycling can be up to 300 km while the longest multiple-stage races can last up to 21 days. Twenty to seventy accelerations are performed during a race, exceeding maximal aerobic power. Training is a crucial component of athletes' preparation for competitions. Therefore, strong emphasis should be on recording the applied training loads and monitoring how they influence aerobic and anaerobic fitness, as well as performance. The aim of the study was to analyze the training loads in the preparatory period and their effects on aerobic and anaerobic fitness in adolescent road cyclists.

Materials and Methods: The study involved 23 highly trained/national elite male road cyclists. Of them, 16 athletes (age: 16.2±1.1 years; training experience: 5.0±2.1 years) fully completed all components of the study. Aerobic fitness was measured using cardiopulmonary exercise testing (graded exercise test to exhaustion), while anaerobic fitness was evaluated using the 30-second modified Wingate anaerobic test. Each recorded training session time was distributed across training and activity forms as well as intensity zones.

Results: The endurance training form used in the preparatory period was characterized by low-volume (~7.7h×wk^{-1}), non-polarised (median polarization index 0.15) pyramidal intensity distribution (zone^1~68%; zone^2~26%; zone^3~1% total training volume). Endurance (specific and non-specific) and strength training forms accounted for ~95% and ~5% (respectively) of the total training time.

Conclusion: Low-volume, non-polarised pyramidal intensity distribution training is probably not an effective stimulus for improving physical fitness in adolescent road cyclists. Disregarding high-intensity exercises in training programs for adolescent cyclists may result in stagnation or deterioration of physical fitness.

Introduction

Road cycling competitions are very demanding in some respects. Analysis of road cycling races has shown that the average distance covered during a competition is 53km (1.4h) in youth, 77-94km (2.0-2.4h) in juniors, and 150km (3.9h) in elite cyclists [1,2]. Interestingly, during such long-lasting competitions, work intensity may be very high.

The percentage of the total flat race time in professional cyclists at an intensity below 70%, between 70 and 90%, and above 90% of maximal oxygen uptake (VO_2max), averages at approximately 70, 25, and 5%, respectively [3]. During the race, approximately 20 to 70 accelerations are performed at an intensity exceeding maximal aerobic power [4]. Moreover, male cyclists may generate power of over 1,200W ($17W \times kg^{-1}$) during final sprints [5]. What is more, data indicates that competitions in younger categories can be even more intense than those in elite cyclists in terms of internal intensity [2].

From a physiological perspective, sports performance in cycling competitions is determined by both aerobic [3,6] and anaerobic fitness [5,7]. The gold standard for evaluation of aerobic fitness is cardiopulmonary exercise testing (CPET), combining the measurement of: (i) physiological variables such as heart rate (HR), pulmonary ventilation (VE), volume of oxygen uptake (VO_2), and exhaled carbon dioxide (VCO_2); (ii) work rate (e.g. power output) and rating of perceived exertion (RPE) during the graded exercise test (GXT) to exhaustion [8]. For practitioners, the most important indices obtained from GXT are VO_2max and power output per kilogram of body mass at metabolic thresholds and VO_2max [9]. Furthermore, the Wingate anaerobic test (WAT) is widely used to assess anaerobic fitness [10]. Classic WAT requires pedaling for 30s at maximum speed against constant resistance. During the test, consecutive crank revolution times are recorded. Based on the obtained data, the following anaerobic fitness indices are calculated: peak (PP), mean (MP), and minimal (MinP) power (absolute and relative), time to obtain peak power (TOPP), and fatigue index (FI).

Training is a crucial component of athletes' preparation for competition. Therefore, strong emphasis should be on recording the applied training loads and monitoring how they influence physical fitness and performance. Training load can be categorized as either internal or external [11]. Internal training loads are defined as relative biological (both physiological and psychological) stressors imposed on an athlete during training or competition. Measures such as heart rate, blood lactate, oxygen consumption, and ratings of perceived exertion are commonly used to assess internal load. On the other hand, external training loads are objective measures of the work performed by an athlete during training or competition and are evaluated independently of internal workloads. Common measures of external load include power output, speed, acceleration, time-motion analysis, global positioning system, and accelerometer-derived parameters. An inexpensive and widely applied method of quantifying training loads in the practice of endurance sports is the time-in-zone approach [12]. This method is based on the measurement of HR and duration of training spent in 3 intensity zones determined individually in relation to HR at metabolic thresholds. However, the drawback of this method is the underestimated time of high-intensity training [12].

Reporting applied training loads and their effects on physical fitness or performance in various athlete populations using scientific approaches can be relevant for practitioners and scientists. Such data may provide a starting point for designing training programs and/or explaining their positive effects (performance improvement), and prevention of potential negative or no effects of the load used (injury, overtraining). To the best of our knowledge, researchers mainly concentrate on the analysis of internationally competitive training loads in adult cyclists, generally employing a retrospective study design [13–21], while there is a very limited amount of data from studies on adolescent road cyclists [22,23] or research in which the prospective scheme was employed [24]. Therefore, the aim of the study was to analyze training loads applied in the preparatory period and their effects on aerobic and anaerobic fitness in adolescent road cyclists.

Material and Methods

Study design

The study was conducted in Świdnica, Poland (at an elevation of 250 meters above sea level), in a ventilated gymnasium. Basic anthropometric indices and physical fitness were assessed (over the span of 4 days) before and after an 18-week preparatory period (PrPe) (November-March), during which training loads were recorded. GXT and MWAT were performed between 10:00 a.m. and 4:00 p.m. at an ambient temperature of 20 ± 1°C and relative humidity of 40 ± 5%. Athletes were tested at the same time of the day (± 1h) before and after PrPe to avoid the influence of circadian rhythm. Participants were asked to remain well-hydrated, to refrain from consuming any stimulants for at least 24h before testing, and not to engage in strenuous exercise at least 48h prior to testing. Assessments were performed in the following order: anthropometric measurements (fasting and after using the toilet), GXT (minimum 2 hours after the last meal), and MWAT (minimum 1 hour after GXT). Before each test, the cyclists were familiarized with the testing procedures. Stress tests were performed on a Cyclus 2 ergometer (RBM electronic-automation GmbH, Germany) with the athlete's bike installed (the same bike on which the athlete trained and competed in races).

The ergometer was calibrated in accordance with the manufacturer's recommendations. All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. Consent to perform testing was provided by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 249/KBL/OIL/2021).

Participants

The study involved 23 male road cyclists recruited from students of the Sports Championship School of Cycling in Świdnica, Poland. Finally, material for analysis was taken from 16 athletes (age: 16.2±1.1 years; training experience: 5.0±2.1 years) who fully completed all components of the study. The basic characteristics of the cyclists are presented in Tab. 1. Seven cyclists withdrew from the tests without giving a reason. The inclusion criteria were: (i) progression of biological development - minimum third pubic hair stage on Tanner's Scale [25]; (ii) "highly trained/national elite" level according to McKay's participant classification framework for research in sports sciences [26]; (iii) having a current certificate from a sports medicine doctor regarding the ability to practice road cycling. The exclusion criteria were age above 18 years or the health status making it impossible to perform the stress tests. The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Anthropometric measurements

Body height (BH) was measured using a Seca 213 stadiometer (Seca GmbH & co. kg, Germany) to the nearest 1 mm. Body mass (BM), fat mass (BF), and lean body mass (LBM) were evaluated by means of an MC 780 MA body composition multi-frequency (5kHz/50kHz/250kHz) octopolar analyzer (Tanita, Japan) using the method of electrical bioimpedance [27]. The measurements were conducted under conditions recommended by the analyzer's manufacturer.

Graded exercise test

The graded exercise test began with a 4-minute warm-up performed at 80W. Next, the load was increased by 40W every 2 minutes. The effort was continued until exhaustion, which was manifested in the inability to maintain a cadence higher than 70rpm. During testing, the following physiological variables were recorded breath-by-breath using a Quark CPET ergospirometer (Cosmed, Italy): VE, VO_2 and VCO_2 and HR. The data were averaged across 10-s intervals. The ergospirometer was calibrated according to the manufacturer's instructions. Rating of perceived exertion (RPE) was recorded in the last 15s of each 2-minute interval using the 6-20 Borg scale [28]. Anaerobic threshold (AT) and respiratory compensation point (RCP) were determined based on the dynamics of change in respiratory indices [29]. The following criteria [30] were used for VO_2max determination: an increase in VO_2 of $<150 mL \cdot min^{-1}$ with an increase in power, respiratory exchange ratio >1.10, RPE >18 on the Borg's scale, age-predicted maximal HR >90% calculated according to Tanaka [31].

Modified Wingate anaerobic test

At baseline, the participants performed a 4-minute warm-up at 90W. During the final 3-5s of the second and fourth of the warm-up, the athletes performed maximal accelerations. Two minutes after the warm-up, the maximal 30-s all-out effort with a stationary start was performed. The resistance applied during the test was set at 10% body mass [32]. At the "Go!" command, the task of the participant was to reach the maximum pedaling rate as quickly as possible and then maintain it in a seated position until the end of the effort (with strong verbal encouragement). Based on the MWAT, the following indices were evaluated: PP, TOPP, MP, MinP, and FI, calculated as ((PP-MinP)÷PP)×100%.

Training monitoring

Training load analysis was conducted based on the data recorded by the Edge 530 sport tester (Garmin, USA) and exported first to the Garmin Connect platform and then to Excel. Each recorded training session times were distributed across training form [33] (endurance, strength), activity form [33] (specific: spinning, road, track, or mountain cycling; non-specific: running, cross-country skiing, skating, swimming), and exercise intensity [34] ($zone^1$: below HR_{AT}; $zone^2$: between HR_{AT} and HR_{RCP}; $zone^3$: above HR_{RCP}) using a time-in-zone approach [12]. Moreover, the polarization index was calculated on a weekly basis according to Treff et al. [35].

Statistical analysis

Statistical analysis was carried out using Statistica 13.3 software (TIBCO Software Inc., Palo Alto, CA, USA). Changes in variables were evaluated with the two-tailed paired samples *t*-test or Wilcoxon signed-rank test depending on normal data distribution, which was examined with the Shapiro-Wilk test. The probability of type-I error below 0.05 was adopted as the level of significance. The effect size for the paired *t*-test samples was calculated by dividing the mean difference by the standard deviation of the difference, while the Wilcoxon signed-rank test, was calculated by dividing the z-value by the square root of the observation number [36]. Test power was calculated post-hoc using G*Power 3.1.9.7 software (input variables: 2-tail, effect size, $\alpha=0.05$, sample size=16).

Results

Anthropometric indices

After the 18-week PrPe, an increase in body mass was observed as a result of a rise in lean body mass. Detailed changes in anthropometric indices are presented in Table 1.

Table 1. Anthropometric characteristics (median (1st and 3rd quartiles)) of the cyclists studied

	pre-test	post-test	Difference (%) pre-post	*p*-value	ES	*p*
Body height (cm)	178.0 (174.3-180.5)	178.3 (174.8-180.8)	0.3 (-0.3-0.4)	0.738	0.24	0.23
Body mass (kg)	64.5 (59.8-68.1)	65.5 (62.4-69.9)	2.5 (0.9-4.6)	0.004*	0.87	0.95
Fat mass (kg)	10.1 (8.7-11.7)	9.8 (9.2-12.5)	2.5 (-3.2-8.22)	0.317	0.27	0.27
Fat mass (%BM)	15.6 (14.8-17.6)	15.9 (14.0-17.8)	-0.4 (-4.0-5.8)	0.947	0.02	0.05
Lean body mass (kg)	54.0 (50.7-57.7)	54.8 (52.3-59.4)	2.0 (1.0-4.7)	0.002*	0.99	0.98

p-value – probability of type-I error, * – statistically significant difference, ES – effect size, P – test power

Aerobic performance

Following the 18-week preparatory period, P_{AT} (W and W×kg^{-1}), P_{VO2MAX} (W), and VO_2max (L×min^{-1}) improved significantly. No changes in P_{AT} (W×kg^{-1}), P_{RCP} (W and W×kg^{-1}), or VO_2max (mL×kg^{-1}×min^{-1}) were found, whereas P_{VO2MAX} (W×kg^{-1}) deteriorated substantially. Detailed data regarding changes in aerobic fitness indices are shown in Table 2.

Table 2. Indices of aerobic performance (median (1st and 3rd quartiles)) before and after the 18-week preparatory period

	pre-test	post-test	Difference (%) pre-post	*p*-value	ES	*p*
P_{AT} (W)	200 (200-200)	200 (200-240)	16.7 (0-16.7)	0.012*	0.63	0.63
P_{AT} (W×kg^{-1})	3.0 (2.9-3.2)	3.3 (3.0-3.6)	12.9 (-1.4-16.6)	0.014*	0.75	0.80
P_{RCP} (W)	280 (280-320)	320 (280-320)	0.0 (0.0-12.5)	0.059	0.47	0.40
P_{RCP} (W×kg^{-1})	4.6 (4.2-4.7)	4.6 (4.4-5.0)	-0.4 (-3.3-9.1)	0.207	0.35	0.26
P_{VO2MAX} (W)	360 (360-400)	400 (400-400)	9.1 (0.0-10.0)	0.025*	0.56	0.53
P_{VO2MAX} (W×kg^{-1})	6.2 (6.0-6.5)	6.1 (5.8-6.3)	-2.3 (-4.6-(-0.7))	0.008*	-0.81	0.86
VO_2max^A	3.82 (3.65-3.94)	4.10 (3.85-4.14)	5.4 (1.6-7.6)	0.002*	1.02	0.97
VO_2max^R	58.5 (57.5-61.4)	60.5 (57.8-63.0)	2.5 (-2.9-5.3)	0.065	0.53	0.51

P – power, HR – heart rate, VE – pulmonary ventilation, VO_2 – oxygen uptake, AT – anaerobic threshold level, RCP – respiratory change point level, max – maximal level, ^{A} - L×min^{-1}, ^{R} - mL×kg^{-1}×min^{-1}, *p*-value – probability of type-I error, * – statistically significant difference, ES – effect size, *P* – test power

Anaerobic performance

After the preparatory period, no changes were found in PP (W), TOPP, or MP (W). Furthermore, relative PP, MP, and FI substantially decreased. Detailed data are shown in Table. 3.

Table 3. Anaerobic performance (median (1st and 3rd quartiles)) before and after the 18-week preparatory period

	pre	post	Difference (%) pre-post	*p*-value	ES	*p*
PP (W)	913 (889-974)	905 (851-983)	-1.8 (-7.6-2.3)	0.183	-0.36	0.27
PP (W×kg^{-1})	14.3 (13.9-14.9)	13.8 (13.0-14.2)	-5.3 (-10.7 to -1.5)	0.015*	-0.71	0.76
TOPP (s)	3.05 (2.40-3.77)	3.55 (2.95-4.40)	0.35 (-0.33-1.33)	0.133	0.41	0.34
MP (W)	736 (685-778)	724 (662-776)	-2.6 (-5.3-1.4)	0.134	-0.41	0.34
MP (W×kg^{-1})	11.4 (11.2-11.5)	10.9 (10.2-11.3)	-4.9 (-9.0 to -2.5)	0.002*	-0.99	0.96
FI (%)	42.9 (39.3-49.5)	38.6 (36.6-41.8)	-8.4 (-23.5-0.3)	0.004*	-0.89	0.91

PP – peak power, TOPP – time do obtain peak power, MP – mean power, FI – fatigue index, *p*-value – probability of type I error, * – statistically significant difference, ES – effect size, P – test power

Training loads

Numerical data for training volume across training forms, activity forms, and intensity zones are presented in Table 4. A graphical representation of training volume in 18 consecutive 7-day mesocycles for training forms, intensity distribution, and polarization index are presented in Figures 1 and 2.

Table 4. Training volume [h×wk^{-1}] (median (1st and 3rd quartiles)) distributed across training forms, activity forms, and intensity zones

Training form	Activity form	Zone^{1}	Zone^{2}	Zone^{3}	∑ Zone$^{1-3}$
Endurance	**Specific**	4.2 (3.7-6.7) 60.0%T	1.5 (1.2-2.4) 23.1%T	0.1 (0.0-0.1) 0.9%T	5.8 (5.0-9.2) 84.0%T
	Non-specific	0.4 (0.0-0.9) 7.6%T	0.3 (0.0-0.5) 3.5%T	0.0 (0.0-0.0) 0.4%T	0.7 (0.0-1.5) 11.5%T
	Overall	5.6 (4.1-7.0) 67.6%T	2.2 (1.5-2.5) 26.6%T	0.1 (0.1-0.1) 1.3%T	7.7 (5.5-9.5) 95.5%T
Strength	N/A	N/A	N/A	N/A	0.2 (0.1-0.6) 4.5%T
Total training volume (T) = 7.9 (6.5-10.0)			Polarization-Index = 0.15 A.U. (0.08-0.24)		

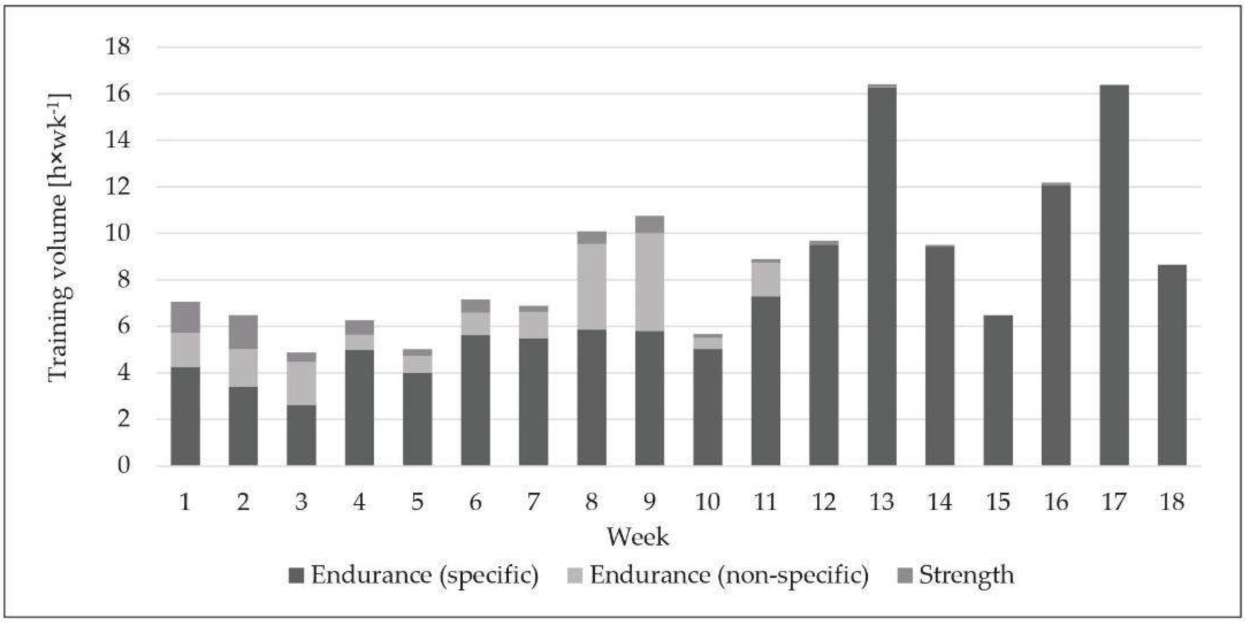

Figure 1. Endurance (specific, non-specific) and strength training volume during each 7-day mesocycle

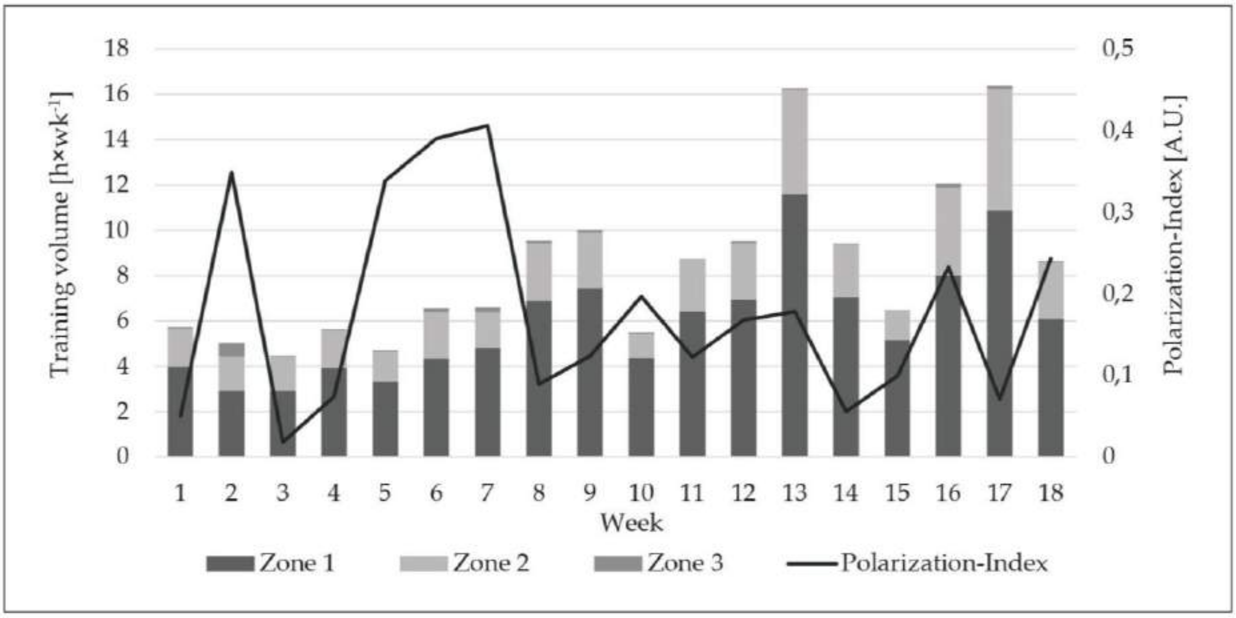

Figure 2. Training intensity distribution and polarization index during each 7-day mesocycle

Discussion

The main finding of this study was that training loads of Polish youth road cyclists in the PrPe period were characterized by low volume and non-polarized pyramidal intensity distribution. What is also significant, the training model implemented in this study had in general no positive effects on either aerobic or anaerobic fitness. To the best of our knowledge, this is one of the first studies in which training loads and their effects on physical fitness in adolescent road cyclists are assessed prospectively.

Training volume and intensity distribution are crucial parameters characterizing sports training. Endurance athletes typically train from 500 hours per year (~10h per week) (distance runners) [37–43] to over 1,000 hours per year (~20h per week) (rowing, swimming, cycling, triathlon) [21,22,44–50] in order to reach an international level. The adolescent road cyclists in the present study trained approximately for 7.9 hours per week during PrPe. Low training volume in the cyclists studied compared to other endurance athlete populations may result from sports level and/or age differences. Furthermore, it should be noted that the preparatory period fell in the winter season. In Poland at this time of the year, temperatures often fall below 0°C, which makes long bike rides difficult.

Many studies across a broad range of endurance sports that have analyzed training intensity distribution (TID) based on the binary approach were consistent with the finding that 75–90% of all endurance training time is performed at low intensity (below the first metabolic threshold). The remaining 10–25% is comprised of high-intensity training performed above the first metabolic threshold [21,33,37,38,49–51]. In the cyclist studied, endurance training time below and above AT accounted for approximately 68 and 27% (respectively) of total training time. The remaining 5% was intended for strength training. The polarization index (median 0.15) and 3 intensity zone approach (zone^1: ~68%, zone^2: ~26%, zone^3: ~1%) used in this study indicated non-polarised [31], pyramidal [9] TID, in which most training was at zone^1, with decreasing proportions of zone^2 and zone^3. This TID model seems to be commonly applied in elite cyclists. This has been shown in the research by Lucia et al. [19] (78%/17%/5%), Zapico et al. [21] (78%/20%/2%), and Schumacher and Mueller [20] (94%/4%/2%).

We believe that the simultaneous increase in P_{AT} (W and W×kg^{-1}), P_{VO2MAX} (W), VO_2max (mL×min^{-1}), plateau P_{AT} (W×kg^{-1}), P_{RCP} (W and W×kg^{-1}), and VO_2max (mL×kg^{-1}×min^{-1}); and decrease in P_{VO2MAX} (W×kg^{-1}), was the result of increased LBM. Kim et al. [52] and Maciejczyk et al. [53] demonstrated substantial positive correlations between LBM (the main component of which is muscle mass) and absolute indices of aerobic performance. We assume that the factor that was likely to increase LBM in the cyclists studied was strength training, which constituted approximately 5% of the total training volume. Such a combination of endurance (ET) and strength (ST) training is called concurrent training (CT). It stimulates both target peripheral (muscular) adaptations, i.e. hypertrophy and capillarisation [54]. In a meta-analysis performed by Wilson et al. [55], it was demonstrated that CT, compared to ET, produces substantially greater improvement in muscle hypertrophy (mean overall effect size of 0.85 [95%CI: 0.57-1.20] vs. 0.27 [95% CI:

-0.53-0.60]). Another plausible explanation for the increase in LBM is the passage of time (the pubertal period is characterized by dynamic tissue growth and maturation) [56], taking supplements promoting muscle hypertrophy [57], or an interaction effect of these factors [58]. Whatever the cause, the changes are adverse in the context of performance because each additional kilogram of BM produces metabolic heat [59] and requires the supply of energy substrates [60], which additionally burdens the body during long-lasting races.

Following the 18-week PrPe period, anaerobic fitness deteriorated in the studied cyclists. The reason for this is probably the characteristics of the applied training loads, with a small number of high-intensity exercises (analysis of cyclists' training loads showed that only approximately 1% of total training volume constituted exercises above RCP intensity). Low-intensity training is thought to be fundamental in the preparation for endurance events. This type of exercise improves VO_2peak by increasing stroke and plasma volume and inducing molecular adaptations for capillary and mitochondrial biogenesis, thereby improving the efficiency of key metabolic components for energy production [61,62]. However, it cannot be expected that this type of exercise will prepare athletes for anaerobic effort [63].

The practical conclusion of this study is that if, for some reason, coaches of adolescent road cyclists cannot include low-intensity training with a volume providing desirable adaptive changes or high volume, low-intensity training is ineffective. A good solution can be the implementation of a more polarised training model by adding high-intensity exercises (above RCP or VO_2max). In the meta-analysis performed by Engel et al. [64], it was suggested that young athletes performing high-intensity training can improve both aerobic and anaerobic performance. Moreover, young athletes may benefit from high-intensity training as it requires less time per training session, leaving more time for training sport-specific skills or school education.

The limitations of this study include (i) the small sample size which does not guarantee high test power (for 12 of the 20 indices, test power was below 80%), (ii) the lack of a control group, (iii) the method used to quantify training loads, which underestimates high-intensity training duration [12], (iv) a lack of detailed data about the applied strength training and supplementation.

Conclusions

Low-volume non-polarised pyramidal intensity distribution training is probably not an effective stimulus to improve physical fitness in adolescent road cyclists. Disregarding high-intensity exercises in training programs for adolescent cyclists may result in stagnation or deterioration of physical fitness.

Founding: The study was funded by the "Research of Young Scientists'' programme provided by the University of Physical Education in Kraków, project No. 144/MN/IS/2021.

Institutional Review Board Statement: All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. Consent to perform testing was provided by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 249/KBL/OIL/2021).

Informed consent statement: The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

Conflict of interest: There is a conflict of interest because one of the co-authors is an editor of the journal. We assure that in such cases, the manuscript has been processed by an independent editor in accordance with the principles of ethics, peer review, and publishing.

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Citation:
Zając B, Gaj PK, Ambroży T: Analysis of training loads in Polish adolescent road cyclists in the preparatory period and their effects on physical fitness. Journal of Kinesiology and Exercise Sciences. 2024;104(35):strony.

9. Wnioski poznawcze i aplikacyjne

Treningi dojrzewających kolarzy szosowych, wiążące się z koniecznością długotrwałego przebywania w pozycji rowerowej, mogą prowadzić do deficytów funkcjonalnych w obrębie kompleksu lędźwiowo-miedniczo-biodrowego i tułowia. W związku z tym zaleca się włączanie do ich programów treningowych ćwiczeń korygujących ukierunkowanych na wzmacnianie, stabilizację i mobilizację tych segmentów ciała. Ponadto, stosowanie testów Functional Movement Screen i Lower Quarter Y-Balance do identyfikacji kolarzy o podwyższonym ryzyku urazu przeciążeniowego nie jest rekomendowane z powodu ich niskiej trafności prognostycznej.

Zmęczenie wywołane wysiłkiem beztlenowym zakłóca działanie systemu kontroli równowagi u dojrzewających kolarzy szosowych, co może przyczyniać się do wzrostu ryzyka upadków podczas zawodów i treningów. Informacja ta powinna być uwzględniona przez organizatorów wyścigów kolarskich, szczególnie w kontekście zabezpieczania kluczowych sektorów wyścigów. Chodzi o odcinki trudne technicznie, gdzie z dużym prawdopodobieństwem kolarze mogą doświadczać zmęczenia beztlenowego. Przykładem mogą być technicznie wymagające zjazdy, które mają miejsce po rywalizacji o górską premię. Poczyniona obserwacja powinna również skłonić szkoleniowców do włączania do programów treningowych ćwiczeń prewencyjnych, skupionych na kształtowaniu kontroli równowagi w warunkach zmęczenia beztlenowego.

Analiza obciążeń treningowych kolarzy szosowych, uczestniczących w badaniu, wykazała, że realizowany przez nich program treningowy w okresie przygotowawczym charakteryzował się niską objętością (~8h×tydz.$^{-1}$), a także niespolaryzowanym i piramidalnym rozkładem intensywności. Taka specyfika obciążeń treningowych okazała się nieskuteczna w kontekście poprawy wydolności tlenowej oraz beztlenowej. Jako racjonalne rozwiązanie w kolejnych iteracjach procesu przygotowawczego dojrzewających kolarzy szosowych należy rozważyć zastosowanie większej całkowitej objętości pracy treningowej przy zachowaniu przyjętej struktury intensywności, lub zwiększenie objętości pracy treningowej o wysokiej intensywności (tzn. powyżej drugiego progu metabolicznego), przy niezmienionej objętości całkowitej.

10. Podsumowanie

Ciągła i metodyczna dokumentacja obciążeń treningowych, połączona z systematyczną ewaluacją ich efektów, jest kluczowym działaniem umożliwiającym poprawę skuteczności procesu treningowego. Taki sposób działania otwiera drogę do sukcesywnego doskonalenia programów treningowych, zbliżając trenerów do najbardziej efektywnych rozwiązań w kolejnych iteracjach. Dzięki temu możliwe jest dążenie do poprawy wyników sportowych przy minimalnym nakładzie pracy oraz jednoczesnym utrzymaniu ryzyka wystąpienia negatywnych konsekwencji zdrowotnych na najniższym możliwym poziomie. Ponadto, kluczowe w minimalizowaniu ryzyka wystąpienia problemów zdrowotnych, zwłaszcza urazów, jest dogłębne zrozumienie mechanizmów ich powstawania w konkretnej dyscyplinie sportowej. Poznanie tych mechanizmów pozwala nie tylko na identyfikację czynników ryzyka, ale również na skuteczne wdrażanie narzędzi predykcyjnych i planowanie działań prewencyjnych.

11. Podziękowania

Z wielkim szacunkiem i wdzięcznością, jako autor pracy, pragnę wyrazić podziękowania dla Trenera Waldemara Cebuli za umożliwienie przeprowadzenia badań w SMS w Świdnicy i nieoceniony wkład w rozwój polskiego kolarstwa szosowego. Ponadto, dziękuję Profesor Annie Mice za duże wsparcie mojego rozwoju naukowego.

12. Załączniki

12.1. Oświadczenie o wkładzie procentowym w powstawianiu publikacji A

Kraków, 19.10.2022 r.

Oświadczenie o wkładzie procentowym w powstawaniu publikacji

Oświadczenie dotyczy publikacji:

Zając B, Mika A, Gaj PK, Ambroży T. *Does Cycling Training Reduce Quality of Functional Movement Motor Patterns and Dynamic Postural Control in Adolescent Cyclists? A Pilot Study.* Int J Environ Res Public Health. 2022 Sep 24;19(19):12109. doi: 10.3390/ijerph191912109. PMID: 36231409; PMCID: PMC9566619.

L.p.	Imię i Nazwisko	Wkład procentowy	Podpis współautora
1.	mgr Bartosz Zając	52	Bartosz Zając
2.	prof. dr hab. Anna Mika	23	Anna Mika
3.	mgr Paulina Gaj	10	Paulina Gaj
4.	prof. dr hab. Tadeusz Ambroży	15	[illegible]

Indywidualny wkład każdego autora w proces powstawania publikacji A w formie opisowej zawarty jest w kserokopi artykułu znajdującego się w rozdziale „Publikacja A”, strona 25, sekcja „Author contributions” niniejszej pracy.

12.2. Oświadczenie o wkładzie procentowym w powstawianiu publikacji B

Kraków, 30.01.2023 r.

Oświadczenie o wkładzie procentowym w powstawaniu publikacji

Oświadczenie dotyczy publikacji:

Zając, B.; Mika, A.; Gaj, P.K.; Ambroży, T. *Effects of Anaerobic Fatigue Induced by Sport-Specific Exercise on Postural Control in Highly-Trained Adolescent Road Cyclists*. Appl. Sci. 2023, 13, 1697. https://doi.org/10.3390/app13031697

L.p.	Imię i Nazwisko	Wkład procentowy	Podpis współautora
1.	mgr Bartosz Zając	52	Bartosz Zając
2.	prof. dr hab. Anna Mika	28	Anna Mika
3.	mgr Paulina Gaj	10	Paulina Gaj
4.	prof. dr hab. Tadeusz Ambroży	10	[illegible]

Indywidualny wkład każdego autora w proces powstawania publikacji B w formie opisowej zawarty jest w kserokopi artykułu znajdującego się w rozdziale „Publikacja B”, strona 36, sekcja „Author contributions” niniejszej pracy.

12.3. Oświadczenie o wkładzie procentowym w powstawianiu publikacji C

Kraków. 30.10.2023 r.

Oświadczenie o wkładzie procentowym w powstawaniu publikacji

Oświadczenie dotyczy publikacji:

Zając, B., Gaj, P. K., Ambroży, T. (2024). Analysis of training loads in polish adolescent road cyclists in the preparatory period and their effects on physical fitness. Journal of Kinesiology and Exercise Science, 104(35). DOI: 10.5604/01.3001.0053.9657

L.p.	Imię i Nazwisko	Wkład procentowy	Podpis współautora
1.	mgr Bartosz Zając	70	
2.	mgr Paulina Gaj	15	
4.	prof. dr hab. Tadeusz Ambroży	15	

Indywidualny wkład każdego autora w proces powstawania publikacji C w formie opisowej zawarty jest w kserokopi artykułu znajdującego się w rozdziale „Publikacja C", strona 40, sekcja „Author contributions" niniejszej pracy.

12.4. Zgoda Komisji Bioetycznej na przeprowadzenie badania

Komisja Bioetyczna
przy Okręgowej Izbie Lekarskiej
w Krakowie

Nr 249/KBL/OIL/2021 z dnia 17 września 2021 r.

Na posiedzeniu w dniu 17 września 2021 r. Komisja zapoznała się z wnioskiem (dokumentacja w załączeniu) złożonym przez :

Koordynator Badania: mgr Bartosz Zając

Akademia Wychowania Fizycznego, Szkoła Doktorska, Al. Jana Pawła II 78, 31-571 Kraków
Tytuł badania: „ Analiza obciążeń treningowych kolarzy szosowych o wysokim poziomie sportowym w kategorii junior uczęszczających do szkoły Mistrzostwa Sportowego w Świdnicy"
Do wniosku dołączono:

1. Protokół Badania
2. Streszczenie (podsumowanie) protokołu w języku polskim
3. Informacja dla uczestników badania
4. Formularz świadomej zgody uczestnika badania,
6. Formularz RODO
7. Życiorys naukowy badacza,
8. Lista piśmiennictwa
9. Polisa ubezpieczeniowa OC badacza
10. Polisa Ubezpieczeniowa podmiotu leczniczego

Komisja wyraża zgodę na przeprowadzenia badania na warunkach przedstawionych we wniosku.

Zgoda Komisji dla Ośrodka jest ważna do dnia ważności Polisy Ubezpieczeniowej
Skład i działanie Komisji zgodne z zasadami Dobrej Praktyki Klinicznej (GCP) oraz wymogami lokalnymi
Lista członków Komisji biorących udział w posiedzeniu stanowi załącznik do niniejszego dokumentu.
Pouczenie: W ciągu 14 dni od otrzymania niniejszej opinii Wnioskodawcy przysługuje prawo odwołania do Komisji Odwoławczej za pośrednictwem Komisji Bioetycznej przy OIL w Krakowie

Kraków, dnia 27.09.2021 r.

Przewodniczący Komisji Bioetycznej
przy OIL w Krakowie

Dr Mariusz Janikowski

ul. Krupnicza 11 a, 31-123 Kraków
tel. 12 619 17 12
e-mail: a.krawczyk@hipokrates.org

Konto Komisji Bioetycznej
Bank PKO S.A
65 1240 4650 1111 0000 5149 3957

Komisja Bioetyczna
przy Okręgowej Izbie Lekarskiej
w Krakowie

Lista obecności członków Komisji Bioetycznej przy Okręgowej Izbie Lekarskiej w Krakowie na posiedzeniu w dniu 17 września 2021r.

dr Mariusz Janikowski ....
lekarz– specjalista chorób wewnętrznych,
diagnosta laboratoryjny
Zakład Diagnostyki Katedry Biochemii Klinicznej
Szpitala Uniwersyteckiego w Krakowie

dr med. Stefan Bednarz ....
dr medycyny – specjalista chorób wewnętrznych
I Klinika Chorób Wewnętrznych i Gerontologii
Szpitala Uniwersyteckiego w Krakowie

mgr Jerzy Bilek ....
mgr farmacji
prywatna apteka

ks. dr hab. Jerzy Brusiło ....
Uniwersytet Papieski Jana Pawła II
duchowny, etyk

dr Mirosława Dzikowska ....
Przełożona Pielęgniarek
Szpital Specjalistyczny im. J. Dietla w Krakowie

dr med. Jerzy Friediger ....
dr medycyny – specjalista chirurgii ogólnej
Szpital Specjalistyczny im. S. Żeromskiego w Krakowie

dr Irena Gawrońska ....
lekarz– pediatra, neonatolog
SPZOZ im. Śniadeckiego w Nowym Sączu

mgr Zbigniew Grochowski ....
mgr psychologii
Szpital Specjalistyczny im. Dietla w Krakowie

prof. dr hab. med. Zbigniew Kojs ....
specjalista ginekologii i położnictwa
Szpital Specjalistyczny im. L. Rydygiera Krakowie

Lek. dent. Dariusz Kościelniak ....
Specjalista stomatologii ogólnej i ortodoncji
Gabinet ortodontyczno – dentystystyczny
„Pod Kasztanem"

dr Lech Kucharski ....
lekarz - specjalista chorób wewnętrznych
Szpital Specjalistyczny im. S. Żeromskiego w Krakowie

dr med. Janusz Legutko ....
doktor medycyny –specjalista chirurgii ogólnej
I Katedra Chirurgii Ogólnej
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12.5. Źródło finansowania badania

Kraków, 17.05.2021 r.

Dr hab. Tadeusz Ambroży, prof. AWF
Mgr Bartosz Zając
Instytut Sportu

NN/602-33./21

Dotyczy projektu badawczego: „Analiza obciążeń treningowych kolarzy szosowych o wysokim poziomie sportowym w kategorii junior uczęszczających do Szkoły Mistrzostwa Sportowego w Świdnicy. ”

Uprzejmie informuję, iż ww. projekt został przyjęty do realizacji, środki finansowe zostały przyznane na rok 2021 w wysokości 8 000,00 zł (słownie: osiem tysięcy złotych). Projekt jest zarejestrowany pod numerem 144/MN/IS/2021.
Proszę o złożenie w ciągu 7 dni do Sekcji Zamówień Publicznych planów zakupów na rok 2021 oraz do Działu Nauki i Wydawnictw korekty kosztorysu.

Dalsze finansowanie projektu według złożonej we wniosku specyfikacji będzie możliwe po przyjęciu do druku pracy przez redakcję czasopisma widniejącego na liście Ministerstwa Nauki Szkolnictwa Wyższego z wykazem czasopism naukowych i recenzowanych materiałów z konferencji międzynarodowych z minimalną liczbą na poziomie 100 pkt lub w jednym z czasopism afiliowanych przez AWF w Krakowie.

DZIEKAN
Wydziału Wychowania Fizycznego i Sportu
Dr hab. Wiesław Chwała
profesor AWF

Grafika wygenerowana przez ChatGPT 4.0

Starałem się jak nigdy, a wyszło jak zawsze…