Assessment of selected anthropometric indicators and training parameters in runners and their impact on injury risk and musculoskeletal overloading

Wojciech Wieszczek[1], Hubert Lipiński[1], Marta Szczepańska[2], Sylwia Piotrowska-Brudnicka[3]

[1] Graduate of the Master's Degree in Physiotherapy, Department of Physiotherapy, Faculty of Health Sciences, Wrocław Medical University, Poland

[2] AFA-MED, Centre of Neurorehabilitation, Żary, Poland

[3] Department of Clinical Biomechanics and Physiotherapy in Motor System Disorders, Faculty of Health Science, Wroclaw Medical University, Poland

Correspondence to: Sylwia Piotrowska-Brudnicka, email: sylwia.piotrowska-brudnicka@umw.edu.pl

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Abstract

Background: Running, as a key contributor to overall health, enhances performance, fortifies muscles, and aids in maintaining a healthy body weight. Nevertheless, it is crucial to acknowledge that, akin to any physical activity, running entails a particular risk of injury, particularly affecting the lower extremities.

Aims: The study aimed to identify factors predisposing to musculoskeletal injuries and their most common locations among amateur runners.

Material and methods: A comprehensive study was conducted involving 116 amateur long-distance runners aged 18 to 69 years. The research utilized three distinct questionnaires to gather valuable insights into the runners' musculoskeletal health and training experiences. The Nordic Musculoskeletal Questionnaire (NMQ) provided a systematic assessment of musculoskeletal discomfort and symptoms, while the Oslo Sports Trauma Research Center Questionnaire (OSTRCQ) focused on gathering data related to sports-related injuries. A self-report questionnaire was also employed to delve into individual perspectives and subjective experiences.

Key words

musculoskeletal system, injuries, sport, running, Nordic Musculoskeletal Questionnaire, Oslo Sports Trauma Research Center Questionnaire.

Results: Problems in the past 12 months in the NMQ questionnaire included knee (18%), lumbar spine (18%), hip/ankle (14%), foot (13%), shoulders (11%), cervical spine (10%), thoracic spine (8%), wrists/hands (5%), and elbow joints (3%). Problems in the past seven days on the OSTRCQ questionnaire included knee (44.8%), lumbar spine (37.1%), hip (23.3%), ankle (22.4%), and shoulder (18.1%). A statistically significant positive, strong correlation (R=0.56; p<0.001) was observed between the NMQ and OSTRCQ questionnaires. A statistically significant negative, weak correlation was also observed between the number of kilometers traveled and the NMQ questionnaire R=−0.22; p=0.02 and OSTRCQ (R=−0.32; p<0.001).

Conclusions: The area with the most common localization of pain is the knee and lumbar spine, followed by the hip/thigh and foot/ankle. A significant risk factor for injury involves a history of previous injury. It has been observed that higher training volume can be a preventive factor against experiencing an injury.

Introduction

The widespread adoption of running as a health-promoting activity is undeniably a global phenomenon. Annually, more than 2,000 amateur marathons are organized worldwide, underscoring the pervasive appeal of this sport [1]. Running has evolved into an immensely popular physical pursuit, cherished for its simplicity, minimal equipment demands, and accessibility to individuals without specialized skills. Recent statistics from 2017 reveal that in the United States alone, nearly 60 million individuals actively participate in running, jogging, or cross-country skiing as part of their health and fitness regimen [2]. Additionally, walking for fitness has captivated the interest of over 110 million people, with many motivated to transition into running [2]. This attests to the overarching influence of running as a preferred choice for enhancing overall well-being on a massive scale.

Regular physical activity prevents non-communicable diseases such as heart disease, heart attack, diabetes, and some cancers. By practicing physical activity such as running, the occurrence of hypertension is prevented, and optimal body weight is maintained [3]. Regular running is an essential factor in reducing body weight, leading to a decrease in waist circumference and increased tissue sensitivity to insulin. Thus, people who engage in physical activity are able to protect against developing metabolic syndrome [4]. Running has been shown to reduce mortality from cardiovascular, cancer, neurological, and infectious causes. Women and men who regularly engage in running show higher levels of overall fitness [5].

As a result of running, the processes of neurogenesis are improved, and the normal levels of neurotransmitters, including serotonin, dopamine, endorphin, and norepinephrine, in the central nervous system are maintained. Thus, physical activity does not only affect the body but also the mental sphere and prevents neurodegenerative processes [6]. Running, through its positive effects on the body, can improve health. However, it should not be forgotten that, like any physical activity, it carries the risk of experiencing injury, especially to the lower extremities. Based on previous studies, it was determined that beginner runners have a one-year risk of injury of 27%, followed by 32% in long-distance runners and 52% in marathon runners [7].

Lower extremity injuries are the predominant afflictions among long-distance runners, with reported prevalence varying from 19.4% to 79.3%, contingent on the specific study [8]. The overall prevalence of injuries hovers within the range of 40-50% [9]. Notably, injuries incurred by runners overwhelmingly manifest as overload injuries [7]. The injurious mechanism involves the accumulation of micro-injuries and overload conditions [10]. Among the acute injuries frequently encountered are muscle sprains and strains, contributing to the complex landscape of challenges faced by long-distance runners.

Scientific data underscores a higher prevalence of knee joint ailments among runners compared to other joint issues. The incidence of knee joint pain in runners is intricately linked to the overall condition of the kinetic chain in the lower limb. Any deviation from the biomechanical norm in the foot, ankle joint, and hip introduces heightened stress to the knee joint [11]. Notably, there needs to be more comprehensive research identifying factors that predispose individuals to musculoskeletal injuries, coupled with an evaluation of the specific locations most susceptible to common types of overload disorders attributed to running. This gap in understanding highlights the need for further exploration into the nuanced interplay of biomechanics and musculoskeletal health in the context of running-related ailments.

Aims

This study aimed to identify factors predisposing to musculoskeletal injuries and their most common locations among long-distance runners. The following research hypotheses were made: (1) Individuals with higher BMI are more likely to suffer musculoskeletal injuries; (2) Age is a predisposing risk factor for injury; (3) A history of past injuries increases the risk of developing a new injury; (4) The incidence of injury rises as training volume increases.

Material and methods

Design and settings

The conducted study followed a prospective, observational, and cross-sectional design. Data collection occurred via an online survey hosted on the Google Forms web platform. Accessibility to the survey was facilitated through various channels, including forums catering to amateur runners, sports activity monitoring apps, social media groups dedicated to running, and distribution of leaflets directly to runners during their training sessions. The data collection spanned one month, specifically from October 1, 2021, to October 31, 2021. This intentional timeframe ensured that responses were garnered from runners situated within a comparable phase of their training macro-cycle.

Study group

The study included 116 long-distance runners. The runners were affiliated with amateur sports clubs and associations and trained individually. Inclusion criteria for the study were age ≥ 18 years, practicing running at the amateur level, and minimum distance covered per training unit ≥ 1 km (1000m). In turn, the exclusion criteria were age ≤ 18 years and professional practice of long-distance running. Among the respondents, women accounted for 32.8% (n=38) and men for 67.2% (n=78).

Research tools

The questionnaire was created based on standardized questionnaires: the Nordic Musculoskeletal Questionnaire (NMQ) and the Oslo Sports Trauma Research Center Overuse Injury Questionnaire (OSTRCQ), as well as partly based on the author's questions. The research tools have a high alpha-Cronbach's alpha reliability coefficient ranging between 0.81-0.92 for the NMQ and 0.91 for the OSTRC-Q [12,13].

The NMQ is a standardized tool commonly employed in research and clinical settings to assess musculoskeletal symptoms and discomfort. Developed to capture information about various body regions comprehensively, the NMQ is particularly valuable for investigating work-related or exercise-induced musculoskeletal issues. Typically structured as a self-administered questionnaire, the NMQ prompts respondents to report any musculoskeletal symptoms experienced during a defined period, often the preceding 12 months. The questionnaire is organized into body maps, allowing individuals to specify the location and nature of discomfort or pain they may have encountered. Researchers and healthcare professionals utilize the NMQ to identify patterns of musculoskeletal complaints, understand the prevalence of symptoms across different anatomical regions, and assess the impact of specific activities or conditions on individuals' musculoskeletal health. The comprehensive nature of the NMQ makes it a versatile tool for studying and addressing musculoskeletal issues in various populations, including athletes, workers, and the general public.

The OSTRC plays a pivotal role in advancing sports injury research with a focus on prevention. Established to investigate risk factors, injury mechanisms, and prevention methods, OSTRC developed the Overuse Injury Questionnaire to address limitations in traditional injury surveillance methods. Initially designed for specific anatomical areas, this comprehensive tool evaluates the consequences of overuse injuries across four domains: sports participation, training volume, sports performance, and pain. Administered at regular intervals, it allows for dynamic monitoring of how these consequences evolve over time. The success of the questionnaire led to the OSTRC Questionnaire on Health Problems, a versatile tool capturing all types of athlete health issues. Embraced by elite sports organizations globally, the ongoing review process ensures continual refinement based on user feedback, solidifying OSTRC's position as a pioneering force in sports injury research and clinical monitoring.

Furthermore, a self-reported questionnaire was employed to gather fundamental information about the study participants, encompassing details such as age, gender, weight, and height. Additionally, pertinent data regarding running training were collected, including training experience, engagement in strengthening and preventive exercises, the running surface, foot contact area during running, the number of kilometers covered in the preceding week, the duration of training in the same period, and the incidence of running injuries within the past 12 months. Prior to participation, individuals in the study were explicitly informed that the acquired data would be exclusively used for research purposes, ensuring complete anonymity for all participants.

Ethical considerations

The research protocol obtained ethical approval from the Bioethics Committee at Wroclaw Medical University, Poland, under the reference number KB-527/2021. The study meticulously adhered to the ethical guidelines outlined in the principles of Good Clinical Practice and the Declaration of Helsinki.

Statistical analysis

All statistical analyses were conducted using the Statistica v. 13.1 package (TIBICO, Palo Alto, USA). The study involved the evaluation of both quantitative and qualitative characteristics, each requiring specific statistical tools for comparisons. To delineate the structure of the studied variables, we computed basic descriptive statistics, presenting measures of position and variability. The normality of variable distributions was assessed using the Shapiro-Wilk test. In instances where variables exhibited non-normal distributions, Spearman's nonparametric rank correlation coefficient was employed to determine the strength of relationships between them. To assess whether the presence or absence of strength

training significantly influenced results in light of non-normal distributions, the nonparametric equivalent of Student's t-test for independent samples, namely the Mann-Whitney U test, was utilized. The impact of the foot landing site on results was investigated using a nonparametric Kruskal-Wallis analysis of variance. Counts and structure indices (percentages) were calculated for variables measured on rank and nominal scales. A significance level of 0.05 was employed throughout the analyses to determine statistical significance.

Results

Results of the NMQ questionnaire

The most common location of complaints in the past 12 months reported by respondents through the NMQ questionnaire is the knee and lumbar spine (equally at 18% each). Next behind the aforementioned are the hip and thigh (14%), ankle and foot (13%), shoulder (11%), cervical spine (10%), thoracic spine (8%), wrists and hands (5%) and elbow joints (3%).

Results of the OSTRCQ questionnaire

Based on the extracted data from the OSTRCQ tool, reported complaints by respondents regardless of their intensity, a summary of locations was prepared. The data is presented in **Table 1**.

Analysis of the results in **Table 2** reveals a mean NMQ score of 2.25±2.11, with a corresponding median of 2.00. Similarly, the mean OSTRCQ score is reported as 39.53±55.62, with a median of 21. For variables such as age, height, time spent running, number of kilometers run, NMQ, and OSTRCQ, statistical evidence supporting the rejection of the null hypothesis of normality of variable distributions ($p<0.05$) was identified. Consequently, the alternative hypothesis, indicating highly asymmetric distributions, was accepted. Given the non-normal distribution characteristics, Spearman's rank correlation coefficient was employed for a comprehensive analysis of the relationships between these variables. This nonparametric approach enhances the robustness of the analysis and ensures the validity of the results.

Selected correlations

Analyses were conducted to find correlations between variables: BMI and the frequency of musculoskeletal injuries, age, and the occurrence of injuries. No correlation was found between the aforementioned variables. Subsequent analyses aimed to verify whether past injuries increase the risk of subsequent injuries – the correlation between previous injuries according to the NMQ and the score on the OSTRCQ questionnaire. The analysis of the results presented in **Table 3** provided grounds to assert a statistically significant, positive, and strong correlation of $R=0.56$ ($p<0.001$) between NMQ results and OSTRCQ scores. It can, therefore, be concluded that as the number of injuries increases, the OSTRCQ questionnaire score also rises. Another analysis aimed to verify whether an increase in training volume correlates with an elevated risk of injury. This involved assessing the correlation between the number of kilometers covered and the OSTRCQ questionnaire score, as well as determining whether the NMQ injury count also increased.

Analyses presented in **Table 4** provided grounds to assert statistically significant, negative, and weak correlations in both cases. There was a correlation between the number of kilometers covered and past injuries according to NMQ ($R=-0.22$; $p=0.02$) as well as the risk of injury according to OSTRCQ ($R=-0.32$; $p<0.001$). Therefore, the hypothesis is deemed untrue because the analyses indicate that with an increase in training volume, the risk of injury decreased, and consequently, the number of injuries decreased as well.

Table 1. Location of complaints occurrence according to the OSTRCQ questionnaire.

Location	n	Occurrence
Knee	52	44.8%
Lumbar spine	43	37.1%
Hip	27	23.3%
Ankle/foot	26	22.4%
Shoulder	21	18.1%

Table 2. Descriptive statistics.

Variable	M	SD	Me	Min	Max	p
Age [years]	33.16	10.91	31.50	18.00	69.00	<0.001
Weight [kg]	73.27	12.14	73.50	50.00	105.00	0.14
Height [m]	1.75	0.09	1.76	1.58	1.92	0.02
BMI [kg/m^2]	23.72	2.79	23.86	17.76	32.63	0.15
How many years have you been running?	5.80	5.41	5.00	0.50	30.00	<0.001
How many kilometers have you run in the last week?	27.23	20.09	25.00	0.00	100.00	<0.001
Previous injuries (NMQ)	2.25	2.11	2.00	0.00	9.00	<0.001
Total severity score (OSTRCQ)	39.53	55.62	21.00	0.00	326.00	<0.001

Table 3. Spearman's rank order correlation – past injuries according to NMQ and severity score according to OSTRCQ.

Pair of variables	N	R	t(N-2)	p
NMQ & OSTRCQ	116	0.56	7.29	<0.001

Table 4. Spearman's rank order correlation – distance covered during running and injuries.

Pair of variables	N	R	t(N-2)	p
How many kilometers did you run in the last week? & NMQ	116	-0.22	-2.39	0.02
How many kilometers did you run in the last week? & OSTRCQ	116	-0.32	-3.66	<0.001

Discussion

The most common location of injuries among runners

According to the gathered data in the NMQ questionnaire, it was found that the most common locations of injuries include, in sequence, the lumbar spine, knee joints, hip joints, thighs, feet, shoulders, cervical and thoracic spine, wrists, and hands, and elbow joints. The results of the OSTRCQ questionnaire indicate that the knee is the most frequent site of discomfort, followed by the lumbar spine, hip, ankle joint, and shoulder. A systematic review by Kakouris et al. [14] demonstrates that the knee and shin region account for over half of reported injuries. Comparing the outcomes of our study with those of the systematic review, it becomes evident that, in both instances, runners consistently identify the knee as the primary area where they commonly experience discomfort.

However, a significant difference lies in the occurrence of lower back pain, which in the study by Kakouris et al. [14] is classified as "other" at a rate of 3.7%, while in our study, it reached an identical value to the knee joint (i.e., 18% according to the NMQ questionnaire). The study by Benc et al. [15] confirms the presented order of injury occurrence (i.e., knee, foot/ankle, shin, hip/pelvis). Similar to the aforementioned study, there is a lack of confirmation of a high percentage of lower back pain in our study.

Lower back pain among runners was considered by Maselli et al. [16]. In their systematic review, it was determined that lower back pain among runners occurs, but its prevalence does not differ from that in the general population. It is important to note that the questionnaire in our study did not take into account the possibility of indicating the location of lower limb pain, which, according to reviews and meta-analyses, is often a problematic area to assess.

This is corroborated by the systematic review by Lopes et al. [17], which identified the most common running-related injuries (RRIs) as medial tibial stress syndrome (MTTS) and Achilles tendon tendinopathy. For a more comprehensive analysis of runners' issues, it would be advisable to include the option to report pain in the lower leg and shin. The meta-analysis by Kluitenberg et al. [18] also emphasizes the relevance of incorporating lower leg pain into the analysis, as issues in this area (lower leg and foot combined) accounted for 34.7% of complaints in novice runners, 30.3% in cross-country runners, and 29.9% in marathon preparation runners.

Past injuries and the risk of experiencing a new injury

The analysis of the results provided grounds to assert a statistically significant, positive, and

strong correlation of R=0.56; p<0.001 between NMQ results and OSTRCQ scores. Based on this, it can be concluded that a history of injury significantly influences the likelihood of experiencing a subsequent injury, indicating the significant role of secondary prevention and strengthening weak points due to a previous injury. Several research studies confirm these findings. An analysis of survey results by Dallinga et al. [19], involving 706 individuals, showed that a history of injury is the sole significant risk factor for running-related injuries.

Other researchers, including Van Poppel et al. [20], Saragiotto et al. [21], and Benca et al. [15], also report that the most significant risk factor for experiencing an injury is a previous injury sustained by the athlete. A plausible explanation for this assumption is the incomplete regeneration process of the damaged area and the limitation of functional or protective functions of previously injured tissue [9]. Additionally, previously damaged tissue may alter the movement pattern of the injured person, ultimately leading to damage to other tissues due to overload [19].

Training volume and the risk of injury

The present study revealed that with an increase in training volume, i.e., a greater number of kilometers covered by the athlete, the number of injuries reported in the NMQ questionnaire decreased, as did the risk of overload injuries indicated by the total severity score of the OSTRCQ questionnaire. Based on the obtained data, higher training volume may translate into better motor preparation and training level, serving a preventive role in reducing the risk of musculoskeletal injuries.

Similar observations were presented in a systematic review conducted by Fredette et al. [22]. According to the cited review, there are studies confirming the obtained results, suggesting that higher training volume may be a factor in reducing the risk of injury, such as a 10% reduction in the risk of knee injury in a group of runners covering a greater number of kilometers compared to a group running fewer kilometers. However, the same systematic review also provides results of studies with completely opposing findings. According to these studies, running above 30 km may be a significant risk factor for musculoskeletal injuries [22]. Given the available information, it cannot be conclusively stated whether the results accurately reflect the real impact of the number of kilometers covered on the occurrence of injuries.

Conclusions

BMI does not affect the occurrence of musculoskeletal injuries in runners. This suggests that even an individual with a high BMI does not automatically have a greater risk of injuries during running. This conclusion is based on the analysis of data and observations from various groups of runners with different BMI values.

Age is not a risk factor for the occurrence of injuries. This indicates that the risk of musculoskeletal injuries may be similar regardless of age. However, other factors, such as overall health, level of physical activity, and technical skills, can influence the risk of injuries in different age groups. This topic requires further research to explore these factors comprehensively.

A past injury is a risk factor for the occurrence of a new injury. This means that individuals who have experienced previous musculoskeletal injuries may be more susceptible to subsequent injuries. This susceptibility could arise from weakened stability, alterations in body biomechanics, or the presence of prior tissue damage. Therefore, individuals with a history of injuries should be aware of the risk and take appropriate precautions to avoid further injuries.

Increasing training volume is a factor that reduces the risk of injury. This means that gradually intensifying the intensity, duration, or quantity of training can help the body better prepare for increased loads and build greater resilience against injuries. However, it is essential to note that excessively rapid increases in training volume can lead to overuse and an elevated risk of injuries. Therefore, monitoring training progress appropriately and adhering to the principle of gradually increasing loads is crucial.

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