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PROMOTION OF PHYSICAL ACTIVITY THROUGH HEALTH APPLICATIONS AMONG STUDENTS OF SELECTED UNIVERSITIES – A PRELIMINARY STUDY

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Abstract Mobile health applications provide individuals with a mobile tool that can be tailored to meet various health needs and physical activity goals, which is particularly important during the COVID-19 pandemic and the associated social distancing protocols. The consequence that the pandemic has on the mental health of university students has prompted and increased the demand of physical activity interventions.

The aim of this study was to determine the self-perceived effects of mobile health applications on physical activity participation among university students. Participants included students registered in one of the faculties at a university in Johannesburg.

Data collection took place by means of an electronic questionnaire using Google Forms as a platform, completed by a sample of 192 students.

The findings in the study reflected that majority of university students use health applications to increase physical activity levels or to track current activity levels. Participants also indicated that specific health applications were used to set goals, monitor progress and receive feedback. Aerobic activities proved to be the more popular type of physical activity in comparison to anaerobic activity.

This study concluded that health applications can be used as a tool to facilitate and promote physical activity participation in the university student population.

Key words health applications, physical activity, activity promotion

Introduction

The recent outbreak of the Coronavirus (COVID-19) pandemic has reshaped the landscape of fitness and healthcare, with the resulting objective of limiting the spread of the virus (Guida, Carpentieri, 2021). In pursuit of this objective, healthcare delivery has evolved to digital technologies to ensure that fitness and treatment continue as proficiently as possible (Vaishya, Javaid, Khan, Haleem, 2020). In 2016, there were approximately 8,000 mobile health applications in the Google Play Application Store and more than 20,000 in the Apple Application Store

(Zapata, Fernandez-Aleman, Idri, Toval, 2015). By 2018, it was predicted that the number of smartphone and tablet owners would reach 3.4 billion, and more than 50% of users would have downloaded a health application, proving that smartphones have become an important part of people's daily lives, relying on them to assisting with various tasks through multiple innovative applications (Bhuyan et al., 2016). Lazar, Koehler, Tanenbaum and Nguyen (2015) have analysed numerous ways on how smart devices can be used in our daily routines. Given the fact that 23% of the adult population worldwide do not meet the minimum recommended guidelines for physical activity, they have looked extensively at health technologies such as physical activity trackers, wearable devices, sensors, shoe-worn pedometers, and global positioning systems, to name a few, in an attempt to increase physical activity, decrease the risk of hypokinetic diseases and improve mental health (Mollee, Middelweerd, Kurvers, Klein, 2017; Lazar et al., 2015). Of particular relevance, numerous studies have reported that health applications have contributed to an overall increase in physical activity and decrease in sedentary time amongst its users (Payne, Lister, West, Bernhardt, 2015). A study conducted among college students concluded that the use of technology had a significant impact on their physical activity behaviour (Bice, Ball, Hollman, Adkins, 2019). They determined that smartphone and application use supports individuals in becoming more mindful of their activity and self-aware of the time they spend being physically active (Bice et al., 2018). These applications suggest a range of exercise modes and include instructional videos, features for sharing with friends, and user statistics and norms (Coughlin et al., 2015). Other application features include the tracking of user activities and steps, providing motivational messages, demonstrating correct techniques when exercising, various settings to increase motivation and allowing self-monitoring (Litman et al., 2015). The instructional video features to source health information are especially popular amongst students who do not have prior medical knowledge, but those with prior medical knowledge use health applications more frequently to acquire information (Coughlin et al., 2015). Advances such as this in mobile technology may provide some solutions to global health issues caused by physical inactivity. Given this information, the purpose of this study was to determine the effect that health applications would have on physical activity participation among university students.

Methods

Ethical clearance was obtained from the institution's Research Ethics Committee (REC-01-146-2017). Institutional permission recruit students to participate in the research study was also obtained. Prior to participation, participants were informed of their rights and responsibilities, and the purpose of the research was elucidated. Informed consent to participate as well as to use the results obtained from this study for future research was acquired from participants.

Study design

This study was a descriptive, cross-sectional study with a quantitative approach. A self-administered, electronic questionnaire analysing the use and popularity of health applications, and the ways in which they can be utilised to promote physical activity was distributed to university students.

Study population and sampling strategy

The purposive sampling method was used to recruit participants. All students registered in one of the faculties at a university in the Johannesburg region were invited to participate on a voluntary basis. Upon meeting the

inclusion criteria, a total of 192 students formed the study sample. Participants were required to complete an electronic questionnaire on the Google Forms platform, which was made available by means of a hyperlink posted on the university's Learning Management System. The first page of the questionnaire highlighted the inclusion criteria and consisted of questions pertaining to participants' consent to partake in the study. If consent was not granted, or participants did not meet the inclusion criteria, they were redirected to the end of the questionnaire and were not given access to complete it.

Data Collection

Students registered in one of the faculties at a university in Johannesburg were asked to complete the questionnaire. The questionnaire chosen for this study was adapted from Litman et al. (2015) and Stoyanov, Hides, Kavanagh, Zelenko, Tjondronegoro and Mani (2015). It was loaded in electronic format on Google Forms and consisted of five sections, namely: demographics, mobile application usage, weight management, physical activity, and motivation. Physical activity was assessed in section 4, and in this section, participants were required to indicate whether they used health applications for physical activity, as well as the type of exercise activities offered by health applications and their perceived effectiveness. The questionnaire made use of closed-ended, Likert scale questions and some questions allowed for multiple response answers.

Data analysis

Quantitative data for 192 participants was collected during this study. Descriptive and inferential statistics were computed using the Statistical Package for the Social Sciences (SPSS) for Windows version 24.0 (Green, Salkind, 2016). Split file analysis was applied to compare variables and inferential statistics were used to generalize from the specific sample and population that was used (Holcomb, 2016).

Pilot Study

Prior to the primary study being conducted, a pilot study was done with the purpose of assessing the contextual validity of the adapted questionnaire, the difficulty of the items, ambiguity of questions and the content, understanding and time taken to complete the questionnaire. The pilot study was conducted among 40 participants who were registered students in one of the faculties at a Johannesburg university. All participants met the inclusion criteria and used health related applications on their smart devices. Subsequent to the pilot study, some questions were revised and reworded. The order of the Likert Scale in which answers were displayed was also adjusted to improve statistical analysis. For these reasons, the participants and results from the pilot study were not included in the primary study.

Results

This study explored the effect of mobile health applications on physical activity participation among students registered in one faculty at a Johannesburg university.

Study demographics

The sample size was 192 participants, and its characteristics are tabulated.

Table 1. Sample demographics

		Number (Percentage)
Gender	Male	58 (30.2)
	Female	134 (69.8)
Age	17–22	109 (56.8)
	23–29	53 (27.6)
	30 and older	30 (15.6)

Table 1 indicates that from the total study sample, 134 participants (69.8%) were females, and 58 participants (30.2%) were males. The participants' ages ranged between a minimum of 17 years and maximum age of 30 years. The mean ± SD was 22.7 ±3.7, which indicates that the sample was heterogeneous in terms of age.

Physical activity participation

Participants were asked to report on their self-reported physical activity levels while using a health application centred around physical activity participation. Table 2 highlights the data obtained around setting specific physical activity goals and the influence of goal setting on physical activity participation.

Table 2. Goal setting and physical activity participation while using the health application

		Frequency (Percentage)
Did you set a specific goal to increase physical activity while using the health app	yes	143 (74.5)
	no	49 (25.5)
How did your participation in physical activity change while using the health applications	participation decreased	1 (0.5)
	participation did not change	68 (35.4)
	participation increased	123 (64.1)

Table 2 shows that 143 participants (74.5%) set a specific goal to increase their physical activity levels while using a health application. There were 123 participants (64.1%) that indicated that their participation increased while using the health application, 68 participants (35.4%) reported no change, and one participant (0.5%) reported a decrease in physical activity.

Participants were required to select their main reason for using a physical activity health application. Figure 1 shows that 100 participants (52%) used health applications to track their current physical activity, 63 participants (33%) indicated the reason was to do more physical activity, 31 participants (16%) rely on health applications to facilitate their weight loss goal and 13 participants (6%) use it for work purposes.

Illustrated in Figure 2 are types of physical activity the participants focused on while using the health application. The greatest number of participants, 119 (62%) indicated that they used it for aerobic exercise, 93 participants (48%) for anaerobic exercise such as weigh training, 30 participants (15%) for yoga, 18 participants (9%) for Pilates, and 68 (35%) and 29 participants (15%) for road running and cycling, respectively. The remaining 20 participants (10%) stated that they used the application for other forms of activity which were not listed in the questionnaire.

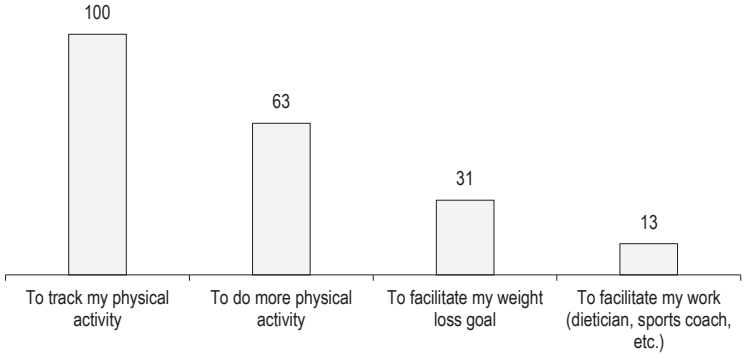

Figure 1. Main reason for using physical activity health applications (n = 192)

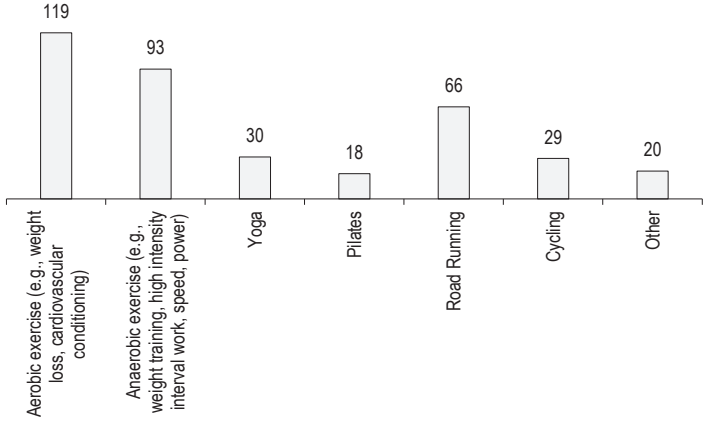

Figure 2. Type of physical activity the user focused on (multiple response)

Discussion

The questionnaire utilized in this study analysed self-reported changes in physical activity in adjunct with the use of health applications. Students registered in a Faculty at a university on Johannesburg formed the study sample.

The novel COVID-19 pandemic has resulted in a decrease in physical activity of a global scale, due to the call to self-isolate (Hammami, Harrabi, Mohr, Krustrup, 2020). The American College of Sports Medicine has released a statement to make use of existing digital platforms to provide physical activity recommendations to individuals who wish to begin exercise programmes and for those who wish to maintain current fitness and strength (Denay et al., 2020). Most of the participants in the present study (74.5%) indicated that they set a specific physical activity

goal while using a health application. This finding is consistent with literature published by Bardus, van Beurden and Smith (2016), who stated that participants often use fitness technology for the purpose of goal setting, self-monitoring, and feedback. A little under a decade ago, approximately 40% of health applications included a goal setting function, such as a daily step count, which prompts users to set their daily step goal prior to using the application (Sullivan, Lachman, 2017). Research has shown that active monitoring together with feedback provided by the health application, can result in the translation of goal setting into an increase in physical activity (Sullivan, Lachman, 2017). This could justify why 64% of the participants in the present study indicated that health applications increased their physical activity levels. Similarly, a study assessing active monitoring on health applications showed that young to middle-aged men regularly made use of health applications and reported increases in physical activity (Saran, Pedrycz, Mucha, Mucha, 2018). In addition, an international study reported that the daily use of health applications on smartphones promoted physical activity in college students with health science-related majors (Penglee, Christiana, Battista, Rosenberg, 2019). Data analysed from January 2008 to January 2017 in a systematic review of 18 randomized controlled tests, concluded that exercise interventions comprising wearables and smartphone applications were effective in promoting physical activity in adults (Gal, May, van Overmeeren, Simons, Monninkhof, 2018). This finding is consistent with the data from the present study as 64.1% of the study population indicated that their physical activity increased while they were using a health-related application. Furthermore, the Eindhoven Running Survey done in 2014 indicated that 86% of the participants that completed the half marathon race reportedly used at least one or two monitoring smart devices over the preceding 12 months (Janssen, Scheerder, Thibaut, Brombacher, Vos, 2017). The results also showed that about 60% of the respondents used a smart sports watch and more than half of the respondents (53.3%) reported the use of applications (Janssen et al., 2017).

Most of participants in the present study cited tracking of physical activity as the mean reason for using health applications. A study conducted in the United States reported that wearable devices and health applications are used for sustained activity tracking in conditioned individuals, as well for initial use in those who are sedentary (Patel et al., 2017). A smaller proportion of the present study's sample (33%) indicated that they used health applications for the latter reason; the purpose of increasing their physical activity. This is consistent with longitudinal studies reporting that sedentary individuals were able to increase their daily steps by 2,500 with the use of step counters (Basset, Toth, LaMunion, Crouter, 2017). University students, particularly during the Covid-19 pandemic, are susceptible to sedentary behaviour, however, a pilot study demonstrated the effectiveness of using health applications to reduce sedentary time and increase the frequency of study breaks (Sui, Prapavessis, 2018).

The types of activities participants preferred to use health applications for varied from aerobic and anaerobic activities to yoga, Pilates, and road running (Schoeppe et al., 2016). In the present study, the three most common activities included aerobic training (62%), weight training (48%) and road running (35%). Similarly, research among children, adolescents and adults reported the aerobic exercises to be the most popular exercises with particular reference to walking, running, soccer and athletics (Hulteen et al., 2017). To corroborate the findings of the present study, previous research also conducted at a South African university revealed that students reported doing moderate- and vigorous intensity aerobic exercise on more days in comparison to strength training (Heeren et al., 2018).

Practical application

This research advocates for the online and remote delivery of health consultations, fitness assessments and exercise sessions. Individuals seeking comprehensive treatment for health conditions or unsupervised fitness routines tailored to their goals can access education-based interventions on mobile applications at a minimal cost. The findings of this study imply that mobile health applications are useful educational tools that can be used by patients and healthcare providers alike to monitor and promote health and wellness.

Conclusion

To conclude, most participants in this research study indicated that whether they were sedentary or physically active, the use of a health application increased their overall participation in physical activity. The promotion of physical activity was also prompted by setting goals related to activity, monitoring progress, and receiving feedback on the health applications, as well as the encouragement of performing activities that participants preferred and enjoyed.

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THE ROLE OF THE SCHOOL IN PREPARING STUDENTS TO LEAD A HEALTHY LIFESTYLE

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This article has undergone a double-blind peer review and has been revised and amended as appropriate.

Abstract Preparation of students for adult life also includes the area of health care. Health education is part of the core curriculum of Polish schools. The leading role of the health educator is assumed by the physical education teacher, but many other educational tasks are carried out by all school staff. The present study attempts to answer the question: How is health education implemented at school? The research project was carried out among students of various colleges in the city of Szczecin, Poland. At the same time, similar studies were conducted among students from other universities in other cities. The research method was a diagnostic survey, with the main assessment tool being the 'Questionnaire for Assessment of Implementation of Physical Education at Secondary School' by K. Górna-Łukasik. On the basis of the study results, an attempt was made to determine the forms and methods of work and the involvement of various types of teachers in health education. Relationships between students' opinions on the methods of implementing the curriculum content, fields of study and gender of physical education teachers were searched for. The study results demonstrate a low degree of implementation of these educational contents. The Polish school offers students few forms of preparation for taking care of their own health.

Key words health education, secondary school, physical education teacher

Introduction

Education and upbringing play an important role in preparing a person for adult life, in particular, to fulfill various social roles. They also affect the formation of desirable social attitudes, including care for one's own and other people's health, the quality of one's own life, society and the environment, which manifest themselves in the display of specific behaviors. Health is the supreme value conditioning human functioning. According to the World

Health Organization health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Health should also be considered in four aspects:

a) physical – the proper functioning of the human body;
b) mental – maintaining internal balance and coping with stress;
c) social – the ability to establish social contacts and functions in the family, school, and professional environment;
d) spiritual – the ability to act in accordance with the accepted system of values (Nutbeam, Levin-Zamir, Rowlands, 2018; Popławska, Jacewicz, 2019; Sentell, Vamos, Okan, 2020; Sęk, Cieślak, 2012; Wolny, 2019; Woynarowska, 2010; Żuchelkowska, 2013).

According to B. Woynarowska, health education is a long-term process in which children and adolescents gain the knowledge related to health and the ways of maintaining and improving it. They also acquire habits and skills that are conducive to creating the right conditions for health and coping with conditions of illness or disability (Woynarowska, 2010). On the one hand, health education provides school students with the awareness about health and life-threatening factors, and on the other hand, with the knowledge about increasing health potential, including the principles of healthy lifestyle and coping with new situations (Bulska, 2017; Han, 2003; Kędzior, 2019; Obodyńska, 2016; Wolny, 2019). It is also important to emphasize the practical aspect of health education activities aimed at 'the development of practical skills to apply knowledge in everyday life situations' (Szpak, 2020, p. 40). According to the ministerial regulation on the core curriculum in Polish schools, 'health education, (...) carried out consistently and competently, will con-tribute to the improvement of the health condition of the society and the economic pros-perity of the country' (Rozporządzenie…, 2018, p. 311).

Health perception is the subjective process of understanding how the human body functions in health and in disease (Condello et al., 2016; Curi, Vilaça, Haas, Fernandes, 2018; Hallal et al., 2012).

Health education has been included in the core curriculum of general education at all stages of schooling: from kindergarten, through elementary schools, to different types of secondary schools (Rozporządzenie…, 2017, 2018).

Conducting school health education classes contributes to the achievement of objec-tives of the core curriculum for general education through which students get to know themselves, diagnose health problems, in particular, in relation to counteracting the diseases of civilization, learn responsibility for their own and others' health, improve personal and social competencies, strengthen self-esteem, be able to function in everyday life and create an environment conducive to maintaining good health (Kostenecka, 2012; Rogacka, 2019; Schulte-Körne, 2016; Tuszyńska, 2012; Wolny, 2019; Woynarowska, 2011). These objectives are implemented in two ways:

a) subject-oriented – with a clear emphasis on the leading role of physical education (teaching and learning about health within the framework of health education) and the inclusion of health education in the curricula of various subjects;
b) educational and preventive – stressing the axiological dimension (values of health and healthy lifestyle included in the educational programs of disease prevention) (Wolny, 2019, p. 19).

Health education in the new secondary school core curriculum has been included in the educational contents of a number of school subjects, such as biology, foundations of entrepreneurship, modern foreign languages, and geography. However, only in physical education has the component of 'Health Education' been identified together with the specific requirements grouped in four sections: physical development, physical activity, safety in physical

activity, and social competence. Importantly, the themes proposed by the legislators in the above sections are also conducive to attaining health education goals. For example, in the area of physical development, the student will acquire the knowledge about the relationship between physical fitness, health and well-being, and will be able to evaluate his/her own body's reactions to physical exercise of different intensities; in the area of physical activity, the student will know selected relaxation techniques and organizes his/her own weekly physical activity (health training) with respect to health recommendations (e.g. WHO or EU); in terms of safety in physical activity the student will be able to assess the risk of injury associated with some sports and to behave in an emergency situation; finally, in terms of social competence the student will act as an organizer, competitor, judge and supporter in sports competitions and recreational events and will take individual and team initiatives.

Teachers of all subjects, school counsellors, support teachers and school psychologists as well as non-teaching staff, who are an integral part of the school environment, are also responsible for the implementation of the health education content at school. However, the most important role is attributed to the teachers of biology, family life education and physical education. The last – according to many researchers (Linca-Ćwikła, 2016; Ostrowska, 2014; Świtała, Gnitecka, Supiński, 2016; Wolny, 2019) – have a special role in attaining the goals of health education due to their substantive preparation and organizational conditions that allow them to make use of various activation methods and conduct classes in an unconventional way. The role of PE teachers – due to the focus of modern education on 'learning' rather than 'teaching' – has undergone an evolution. Nowadays a PE teacher acts primarily as a guide, leader, advisor, animator, and model of appropriate pro-health attitudes (Rasmus, Stetkiewicz-Lewandowicz, Talarowska, Sobów, 2013). In his/her actions a PE teacher should be open to the needs of students, show respect and understanding, undertake joint actions with both students and their parents and guardians, other teachers and specialists, contribute to the formation of the educational environment, and create situations conducive to the achievement of health education goals (Szpak, 2020). According to M. Ostrowska: 'Authenticity, empathy and acceptance in teacher-student relations create a bridge between upbringing and teaching. Through such targeted educational interactions, we help the students find meaning and values in life, and at the same time, we build the right foundation for the formation of their life skills' (Ostrowska, 2014, p. 73). A physical education teacher, who is also a leader or promoter of health at school, must have the appropriate professional background to optimally implement the contents of health education. For this purpose, it is necessary for PE teachers to have competencies that can be divided into:

a) scientific – related to their level of knowledge, e.g. about health, functioning of the human body, lifestyle diseases, stress, threatening influences, etc.;
b) pedagogical – which enable the selection of appropriate methods, forms and didactic means for the implementation of specific content and the fulfillment of students' expectations and abilities;
c) social – that affect the development of relationships, creating an atmosphere conducive to the acquisition of skills and the formation of desirable habits;
d) organisational – which determine the creation of a material environment and space for educational activities.

Some researchers identify only subject-related competences and pedagogical competences (Czechowski, Żukowska, 2010), while others specify them in more detail. K. Wojciechowska further divides the competences into creative, information and media, moral, diagnostic, cooperation, technical or emotional, among others (Wojciechowska, 2014).

Effective conduct of the educational process in the field of health education should be realized on the basis of a reliable diagnosis of the possibilities, needs and expectations of students; the use of various forms of teaching to motivate and make classes more attrac-tive; the involvement of students in the creation and implementation of class themes; combining information from different sources; presenting models of health behavior with respect to authorities, and organizing conditions for practical activities (Olejniczak-Nowakowska, 2014; Wolny, 2019; Woynarowska, 2011; Wrona-Wolny, Makowska, 2011).

Issues of health education are introduced as part of physical education classes, exttracurricular activities and projects included in the school educational and disease prevention program. In addition – according to the provisions of the core curriculum – the school should create conditions for independent inquiry, problem solving, cooperation, and development of key competencies. This provides teachers with an opportunity to utilize a variety of methods and forms of work with students. Specialists in pedagogy, didactics and education propose to implement – in addition to traditional methods such as lectures, talks, working with texts – various activation methods. B. Woynarowska highlights the significance of such methods as discussion, role plays, portfolios, projects, and visualization. Particular importance is also attached to those ways and forms of student participation in the implementation of health education content, which contain elements of fun, competition, and opportunities to test oneself in practical activities, e.g. sports and recreation festivals (events), quizzes, knowledge competitions, etc. (Woynarowska, 2011).

It is important to note that the quality of provided health education depends not only on the scope of knowledge, teaching, or organizational skills. The effects on interactions and, consequently, on the formation of prohealth attitudes of students also rely on the personality of the health leader, his/her empathy, authenticity and thoroughness in the implementation of tasks, and traits and skills which, unfortunately, the future teacher cannot be equipped in during professional teaching training (Ostrowska, 2014). The effects on the achievement of the assumed goals of health education are conditioned by the functioning and cooperation of all participants in the school environment, namely, the school management, teaching and non-teaching staff, students and their parents, as well as institutions supporting various school activities.

Materials and methods

The present study was conducted as part of a joint research project at the University of Szczecin and the Jerzy Kukuczka Academy of Physical Education in Katowice. A diagnostic survey was conducted among 303 students of the University of Szczecin (194 women and 109 men). The research was conducted in January 2020 in the fields of physical education (74 women, 70 men), tourism and recreation, and sports diagnostics (a total of 120 women and 39 men in both fields of study). The research tool used was the 'Questionnaire for Assessment of Implementation of Physical Education in Secondary Schools' designed by Krystyna Górna-Łukasik. The project was approved by the relevant Bioethics Committee (No. KBI43/17). The reliability assessed with the Spearman-Brown formula and Cronbach's alpha was in the range between 0.86 and 0.96 (Górna-Łukasik, 2017). Corresponding to the research questions, 12 statements were selected for statistical analysis. They were all rated on a five-point Likert scale (1 point – no occurrence of a given form, 5 points – frequent occurrence of a given form). The comparison of results was made for all students, separately for men and women, and for students of physical education and students of other majors. Statistical analysis was performed using IBM SPSS Statistics v. 25. Due to the ordinal nature

of the collected data and the non-equinumerosity of the compared groups, non-parametric tests were applied: the Mann-Whitney U test for two independent groups, and the Kruskal-Wallis H test for three independent groups. In tables, descriptive statistics were presented as means (M) and standard deviation (SD) to increase the visibility of differences between groups. The level of statistical significance was set at $p < 0.05$.

Results

The most common forms of promoting a healthy lifestyle were sports and recreational events (Statement 8). The least frequent form of promoting healthy lifestyles were lectures for parents (Statement 3). The male students more often declared that in their schools lectures on healthy lifestyle had been given by teachers, outside classes for students and parents, teachers of theoretical subjects provided active recreation during classes (e.g. respiratory exercises, in-class physical exercises), and that teachers corrected body posture and emphasized the principles of a healthy lifestyle (Table 1). Statistically significant opinions were recorded in statements 2, 3, 5, 7 and 9.

Table 1. Opinions of all students (n = 303) on the implementation of health education content in their schools

Implementation of health education content	Women, n = 194		Men, n = 109		Mann-Whitney U Test	
	M	SD	M	SD	Z	p
Statement 1	2.21	1.30	2.16	1.29	–0.323	0.747
Statement 2	1.66	1.12	1.97	1.19	**–2.768**	**0.006**
Statement 3	1.24	0.67	1.46	0.95	**–2.069**	**0.039**
Statement 4	3.03	1.22	2.85	1.39	–1.156	0.248
Statement 5	1.64	1.10	2.01	1.36	**–2.108**	**0.035**
Statement 6	3.24	1.45	3.27	1.34	–0.027	0.978
Statement 7	1.79	1.07	2.20	1.30	**–2.731**	**0.006**
Statement 8	3.87	1.09	3.98	1.06	–0.907	0.364
Statement 9	2.36	1.25	2.62	1.19	**–2.114**	**0.034**
Statement 10	2.71	1.32	2.91	1.33	–1.326	0.185
Statement 11	2.70	1.37	2.98	1.35	–1.785	0.074
Statement 12	3.04	1.30	2.81	1.42	–1.522	0.128
Total	29.50	9.04	31.22	10.55	–1.174	0.240

Legend. Statement 1: Talks on health for students by outside experts; Statement 2: Talks on health for students by teachers outside PE lessons; Statement 3: Talks on health for parents; Statement 4: Teachers of other subjects than PE convinced students of the need for a healthy lifestyle; Statement 5: Teachers of other subjects than PE provided students with active recreation during lessons; Statement 6: Sports and recreational events were organized at school for students, teachers and parents; Statement 7: Teachers corrected students' body posture; Statement 8: There was a student-friendly atmosphere at school, Statement 9: The school paid attention to the principles of healthy lifestyles; Statement 10: The school provided opportunities for students to use extracurricular sources of information about health; Statement 11: Teachers organized extracurricular activities and events to promote healthy lifestyles; Statement 12: Competitions and exhibitions on health-related topics were organized at school.
M – mean; SD – standard deviation; Z – Mann-Whitney U test, p – level of statistical significance.

Table 2 presents the opinions of physical education university students about the ways health education had been implemented in their secondary school. There were no significant statistical differences between male and female students' opinions.

Table 2. Physical education students' opinions (n = 144) on the provision of health education con-tents at school

Implementation of health education content	Women, n = 74		Men, n = 70		Mann-Whitney U Test	
	M	SD	M	SD	Z	p
Statement 1	2.26	1.33	2.13	1.30	–0.598	0.550
Statement 2	1.84	1.22	1.91	1.11	–0.751	0.453
Statement 3	1.23	0.65	1.46	0.99	–1.205	0.228
Statement 4	3.09	1.15	2.93	1.44	–0.726	0.468
Statement 5	1.64	1.14	1.90	1.31	–1.268	0.205
Statement 6	3.53	1.41	3.31	1.29	–1.090	0.276
Statement 7	1.92	1.12	2.07	1.31	–0.456	0.648
Statement 8	3.89	1.03	4.01	1.01	–0.798	0.425
Statement 9	2.51	1.23	2.66	1.09	–1.006	0.315
Statement 10	2.68	1.30	2.89	1.14	–1.018	0.309
Statement 11	2.66	1.40	2.84	1.28	–0.932	0.352
Statement 12	3.08	1.31	2.80	1.35	–1.258	0.208
Total	30.32	9.36	30.91	10.01	–0.414	0.679

The opinions of students of other majors presented in Table 3 show that men more than women reported that their schools had provided extracurricular lectures on healthy lifestyles (Statement 2), provided leisure activities during lessons (Statement 5), teachers corrected students' body posture (Statement 7), and organized extracurricular activities and events promoting healthy lifestyles (Statement 11). These correlations were statistically significant (Table 3).

Table 3. Opinions of students in other majors (n = 159) about the health education implementation in their schools

Implementation of health education content	Women, n = 120		Men, n = 39		Mann-Whitney U Test	
	M	SD	M	SD	Z	p
Statement 1	2.18	1.29	2.21	1.30	–0.162	0.871
Statement 2	1.55	1.05	2.08	1.33	**–2.732**	**0.006**
Statement 3	1.25	0.69	1.46	0.88	–1.830	0.067
Statement 4	2.99	1.26	2.72	1.32	–1.181	0.238
Statement 5	1.65	1.07	2.21	1.45	**–2.012**	**0.044**
Statement 6	3.07	1.45	3.18	1.43	–0.419	0.675
Statement 7	1.72	1.04	2.44	1.27	**–3.502**	**<0.001**
Statement 8	3.86	1.13	3.92	1.16	–0.394	0.693
Statement 9	2.27	1.26	2.56	1.35	–1.221	0.222
Statement 10	2.73	1.34	2.95	1.34	–0.933	0.351
Statement 11	2.73	1.36	3.23	1.44	**–1.952**	**0.050**
Statement 12	3.02	1.30	2.82	1.55	–0.869	0.385
Total	28.99	8.84	31.77	11.50	–1.034	0.301

The analysis of the ways in which health education was implemented according to the physical education teacher's sex revealed no significant statistical differences. When dividing the respondents according to their major,

there were also no differences with re-gard to the PE teacher's sex. As far as the physical education students were concerned, there were no respondents who declared that they were taught by both women and men (Tables 4–6).

Table 4. Opinions of all surveyed students (n=303) on the implementation of health education content depending on the PE teacher's sex

Implementation of health education content	PE teacher's sex						Mann-Whitney U Test	
	Women and men n = 86		Women, n = 140		Men, n = 77			
	M	SD	M	SD	M	SD	H	p
Statement 1	2.21	1.29	2.21	1.30	2.12	1.32	0.437	0.804
Statement 2	1.57	1.07	1.84	1.19	1.87	1.17	5.019	0.081
Statement 3	1.20	0.53	1.36	0.88	1.38	0.86	1.167	0.558
Statement 4	3.08	1.24	2.91	1.34	2.94	1.23	1.051	0.591
Statement 5	1.63	1.06	1.94	1.36	1.65	1.05	2.606	0.272
Statement 6	2.97	1.47	3.34	1.39	3.42	1.34	4.743	0.093
Statement 7	1.86	1.12	2.01	1.25	1.90	1.11	0.491	0.782
Statement 8	3.87	1.13	3.93	1.07	3.92	1.05	0.081	0.960
Statement 9	2.31	1.30	2.44	1.24	2.65	1.12	4.799	0.091
Statement 10	2.69	1.42	2.84	1.29	2.78	1.30	1.071	0.585
Statement 11	2.90	1.36	2.78	1.42	2.74	1.28	0.658	0.720
Statement 12	2.97	1.35	3.00	1.34	2.87	1.36	0.502	0.778
Total	29.24	9.18	30.60	9.98	30.22	9.53	0.567	0.753

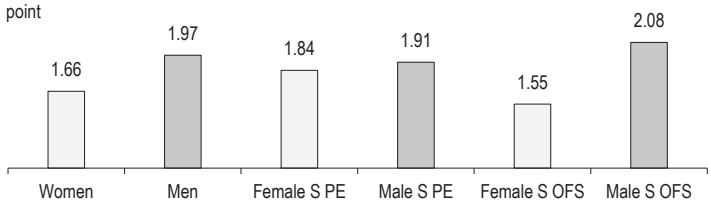
Table 5. Opinions of students of physical education (n = 144) on the implementation of health edu-cation content depending on the PE teacher's sex

Implementation of health education content	PE teacher's sex				Mann-Whitney U Test	
	Women, n = 69		Men, n = 75			
	M	SD	M	SD	Z	p
Statement 1	2.33	1.31	2.07	1.30	–1.285	0.199
Statement 2	1.90	1.18	1.85	1.16	–0.015	0.988
Statement 3	1.32	0.83	1.36	0.85	–0.257	0.797
Statement 4	3.13	1.36	2.91	1.23	–1.062	0.288
Statement 5	1.91	1.41	1.63	1.02	–0.704	0.482
Statement 6	3.46	1.37	3.39	1.35	–0.394	0.693
Statement 7	2.13	1.33	1.87	1.10	–1.024	0.306
Statement 8	4.01	0.99	3.89	1.05	–0.659	0.510
Statement 9	2.55	1.23	2.61	1.10	–0.550	0.582
Statement 10	2.83	1.36	2.73	1.29	–0.380	0.704
Statement 11	2.81	1.43	2.69	1.26	–0.424	0.672
Statement 12	3.06	1.31	2.84	1.36	–1.003	0.316
Total	31.45	10.01	29.84	9.36	–0.674	0.500

Table 6. Opinions of students of other majors (n = 159) on the implementation of health education content depending on the PE teacher's sex

Implementation of health education content	PE teacher's sex						Mann-Whitney U Test	
	Women and men n = 86		Women, n = 71		Men, n = 2			
	M	SD	M	SD	M	SD	H	p
Statement 1	2.21	1.29	2.21	1.30	2.12	1.32	0.437	0.804
Statement 2	1.57	1.07	1.84	1.19	1.87	1.17	5.019	0.081
Statement 3	1.20	0.53	1.36	0.88	1.38	0.86	1.167	0.558
Statement 4	3.08	1.24	2.91	1.34	2.94	1.23	1.051	0.591
Statement 5	1.63	1.06	1.94	1.36	1.65	1.05	2.606	0.272
Statement 6	2.97	1.47	3.34	1.39	3.42	1.34	4.743	0.093
Statement 7	1.86	1.12	2.01	1.25	1.90	1.11	0.491	0.782
Statement 8	3.87	1.13	3.93	1.07	3.92	1.05	0.081	0.960
Statement 9	2.31	1.30	2.44	1.24	2.65	1.12	4.799	0.091
Statement 10	2.69	1.42	2.84	1.29	2.78	1.30	1.071	0.585
Statement 11	2.90	1.36	2.78	1.42	2.74	1.28	0.658	0.720
Statement 12	2.97	1.35	3.00	1.34	2.87	1.36	0.502	0.778
Total	29.24	9.18	30.60	9.98	30.22	9.53	0.567	0.753

Figures 1–7 present opinions of students of various majors on the forms of imple-mentation of health education at school. The mean scores of individual statements, rang-ing from 1–2 points, indicate that lectures for students outside their physical education classes, lectures for parents, active recreation during classes, and correcting students' body posture had been very rarely conducted (Figures 1–4). Slightly more frequent were lectures given by invited speakers from outside the school, e.g. doctors, nutritionists, nurses (Figure 5), and organization of extracurricular activities and health-promoting events (Figure 6). The total of all opinions on the questionnaire questions is between 29.50 and 31.77 out of a possible 60 points. Women's declarations were at a lower level than men's, but they did not differ significantly.



S PE – students of physical education, S OFS – students other fields of study.

Figure 1. Comparison of opinions of students of different majors on teachers' lectures out-side physical education classes

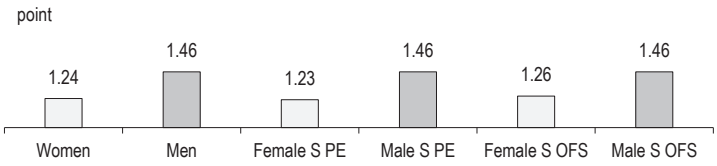


Figure 2. Comparison of opinions of students of different majors on lectures for parents

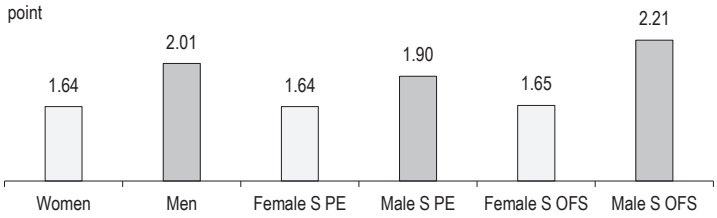


Figure 3. Comparison of opinions of students of different majors on the provision of active recreation during classes conducted by other teachers

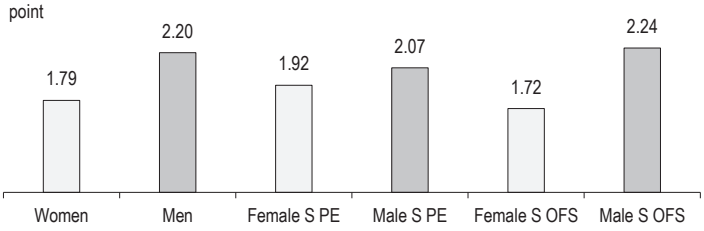


Figure 4. Comparison of opinions of students of different majors on correcting students' body posture

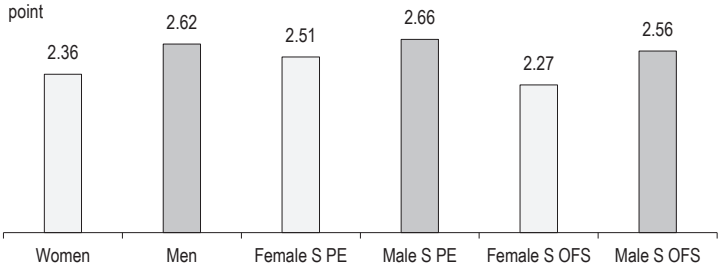


Figure 5. Comparison of opinions of graduate students on lectures given by experts outside school and application of healthy lifestyle principles at school

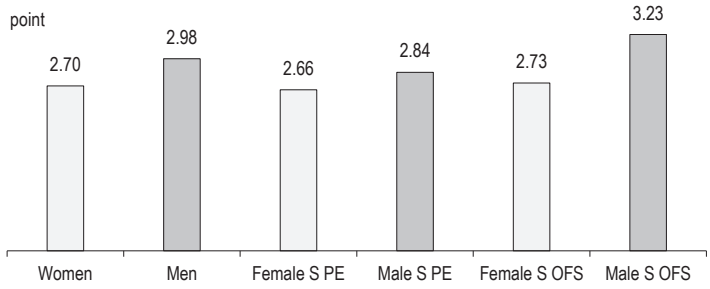


Figure 6. Comparison of opinions of students from different majors on the organization of extracurricular activities and health-promoting events

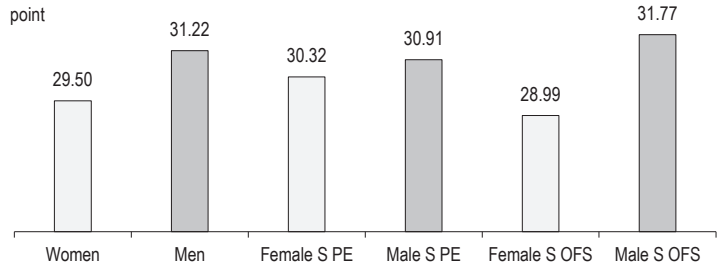


Figure 7. Comparison of opinions of students of different majors on the implementation of health-related educational content (aggregate)

Discussion

K. Borzucka-Sitkiewicz in her survey among health promotion coordinators in institutions participating in the network of Health Promoting Schools, concerning ways of health education implementation, found that more than 86% of respondents reported the implementation of health education within various school courses. Every tenth respondent (12%) admitted that a distinct course had been created to achieve the goals of the program. Among the forms used to convey the health content, teachers made use of school projects, ad hoc events, outdoor trips as well as lectures by outside experts (Borzucka-Sitkiewicz, 2016). K. Łomińska in her survey of teachers of Warsaw schools, found that health education was implemented by physical education specialists, conducting classes in the gym (70.8%), and less frequently in regular classrooms (55.6%) (Łomińska, 2014). P.F. Nowak, in a study on the pop-ulation of teachers in Opole regarding the level of implementation of health education at school, found out that in most institutions various types of pro-health activities had been carried out (Nowak, 2012). M. Zadarko-Domaradzka in her evaluation of health education implementation, based on the opinions of teachers in Opole reported that physical education teachers were the most qualified to teach this subject (Zadarko-Domaradzka, 2015).

Research on students' perception of health education was conducted by Charzyńska-Gula Jaworska, Bogusz, Kocka, Domżał-Drzewicka, Wasil (2013), Kap, Skowronek, Sarnecka (2017), and Świtała, Bukowska (2016). In their study health education themes were found to have been provided in the form of lessons prepared by students, using activating methods, including genre scenes as workshop activities (Truszkiewicz, Olejniczak, Religioni, Skonieczna, 2015) such as first aid, or problem solving in small groups (Charzyńska-Gula et al., 2013). Sources of health knowledge are most often physical education (35.5%) and biology classes (29.4%), with health information also provided in chemistry classes, civil defense courses, and homerooms (Kap, Skowronek, Sarnecka, 2017). According to Warsaw students, classes should be taught by educated specialists in this area (26%) or specialists from outside the school (45%) (Truszczyńska et al., 2015). The vast majority of female students from Łódź (70%) confirmed the need for health education classes, and 2/3 of male students (62%) said they were unnecessary (Szkudlarek, Kaźmierczak, Kowalska, 2016). A similar opinion was collected among female students in Wrocław, who acknowledged that the content implemented in the form of classroom activities was interesting and relevant to their development. Introducing theoretical classes into physical education classes does not – in their opinion – lower the quality of physical activity (Świtała, Bukowska, 2016).

K. Górna-Łukasik and K. Skalik in their research on university students from Katowice, found that sports and recreational events for students, teachers and parents, had been the most common form of implementation of health education, followed by extracurricular activities and other events organized jointly by teachers of physical education and other subjects, and then by competitions and exhibitions on health issues. The situation was similar in the study of Szczecin students. In the opinions of students from Katowice, lectures for parents and lectures delivered by outside experts had been the least frequently implemented forms of health education (Górna, Skalik, 2021). The results were similar among the Szczecin students. Posture correction and organization of active recreation during lessons were rare in both studied school environments.

The majority of respondents negatively assessed the application of healthy lifestyle principles at school (Górna, Skalik, 2021), both in the Katowice and Szczecin studies. Thus, the findings of the Polish Supreme Audit Office critically assessing this component of school functioning can be corroborated (Zaleski-Ejgierd, 2014).

The effects of implemented health education depend not only on the actions taken by PE teachers, who, as previously mentioned, have been assigned the role of health leaders in the education system. Their organizational skills, knowledge, teaching preparation, and 'pedagogical talent' are certainly half of the success. Nevertheless, many teachers claim that they are not fully prepared to implement health education, especially in terms of using activating methods and conducting theoretical classes, and that their hindered access to resources and teaching aids intensify their reluctance to implement health education content in the educational process (Woynarowska, 2010; Gaweł, 2016). Different barriers often arise in the cooperation of so many factors, which makes it difficult to achieve the desired results of 'health science'. In addition to the barriers on the part of the teacher, the financial limitations of educational institutions, lack of training offers for teachers, undervaluation by school principals and representatives of leading bodies of the importance of health education in preparing students for adult life, reluctance of teachers of other subjects to cooperate in the implementation of pro-health tasks, lack of involvement of parents in the life of the school, and thus in the process of health education of their children, as well as time and space limitations should also be indicated. One more important determinant of the effectiveness of health education is the interest and involvement of students themselves.

Conclusions

Perhaps it is thanks to health education – properly implemented, aimed mainly at raising awareness and involvement, allowing students to co-organize the educational space and select content – that attendance at physical education classes will increase, and thus the goals of health education will be achieved. The study results deomonstrate a low degree of implementation of these educational contents. The Polish school offers students few forms of preparation for taking care of their own health. Opinions of students from Szczecin's universities confirm some serious neglect in this area of education. Therefore, it can be assumed that school teachers are insufficiently prepared to fulfil the role of health educators. Their theoretical knowledge does not translate into the development of appro-priate attitudes of their students towards the care for their own and others' health.

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THE INFLUENCE OF LOCKDOWN ON THE PHYSICAL ACTIVITY AND SUBJECTIVE HEALTH IN THE TEACHERS OF PHYSICAL EDUCATION IN POLAND

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Abstract The global COVID-19 pandemic has resulted in restrictions in most countries. One of them was to replace traditional education in schools with online learning. Such a change could provoke a build-up of negative feelings due to insecurity and loneliness. In addition, reducing daily physical activity and closing sports venues can have a detrimental effect on health. The article presents the results of the study of the impact of distance learning on the daily physical activity and condition of physical education teachers in Poland, as well as the subjective perception of physical and mental health in this professional group. Google forms were used to collect the data. The research tool was a questionnaire. The analysis showed that distance learning had a significant negative impact on the physical and mental health of the study group. The impact of distance learning on physical and mental health is gender independent. Teachers more often negatively assessed their physical and mental health compared to the studies in previous years. Daily physical activity of the subjects decreased, and most of them increased their body weight. Less than 3% of the surveyed teachers during the blockade felt happy and full of life.

Key words public health, physical education teachers, lockdown, physical activity, psychological stress

Introduction

On January 30, 2020, the World Health Organization announced the outbreak of epidemics caused by the novel coronavirus to be a public health emergency of international concern. In the same year, in early March, the SARS-CoV-2 virus was detected in 84 countries around the world. In Poland, the first case of infection was recorded on March 4, 2020 (Duszyński et al., 2020). Therefore, an epidemic emergency was introduced in the country which resulted in restrictions in all sectors of economic and public life. All the citizens felt the restrictions personally, as well as individual social groups. Teachers constitute one of the largest professional and social groups in Poland. In the 2019/2020 school year, the total number of full-time jobs in educational institutions was 513,868 predominantly occupied by women 423,120 (82.34%). Most of the teachers worked in primary schools – 270,652, pre-school education institutions – 111,230, and technical schools, high schools and first-degree industrial schools – 112,769 (Główny Urząd Statystyczny, 2020).

In the studies conducted so far in Poland, just a few concern health and health care among teachers, although they are a very important factor influencing the quality of education. The focus has been shifted towards the health of the students. Research relating to teachers treated mainly selected health issues, such as voice disorders or occupational burnout (Łoś-Spychalska, Fiszer, Śliwińska-Kowalska, 2002; Tucholska, 2009). In some European countries, for example in Germany, health surveys of the teacher population were carried out. The published results indicated that the incidence of chronic and long-term diseases is high and has been aggravating in recent years. Most of the diseases are related to the musculoskeletal system, hormonal, neurological and metabolic disorders (Brütting, Druschke, Spitzer, Seibt, 2018). A study of teachers' health in Belgium conducted on a group of N = 1066 people indicated that in terms of both mental and physical health teachers showed lower levels compared to the general population of Belgium (Bogaert, De Martelaer, Deforche, Clarys, Zinzen, 2014). Such disturbing research results and the dynamic changes that took place in the Polish education system in 2020 prompted to conduct an analysis study in the field of teacher health in Poland. For the first time, introduced as a result of the spreading COVID-19 pandemic throughout the country, many months of remote learning changed the system of work, lifestyle, and, in particular, the physical activity of individual groups of school communities, including school employees, students and, to some extent, their parents (Woynarowska-Sołdan, Węziak-Białowolska, 2010).

Among the pedagogical staff in Poland, teachers of physical education (PE) are one of the most numerous groups and this group was selected for the study. The choice of the study population was also influenced by the role that PE teachers play in schools. It is them who play a key role in educating students about health and healthy lifestyle.

Objective of the work

The aim of the study was to determine the impact of lockdown on teachers' health, to find out whether remote work has had an impact on the daily physical activity of this group. The following research questions were asked in the study:

1. Has remote work affected the physical and mental health of PE teachers?
2. Has remote teaching had an impact on the daily activity and physical condition of teachers?

Material and methods

Characteristics of the group and organization of research

The research was carried out in 2021. Due to the ongoing pandemic, the diagnostic survey method and the survey technique were chosen. 1,498 physical education teachers, including 49.11% women, participated in the study. The respondents taught in primary schools (75.32%), in secondary schools (23.55%) and other types of institutions (1.13%). Teachers had various levels of professional advancement, i.e. a certified teacher (81.10%), appointed teacher (11.35%), contract teacher (6.54%) and trainee (1.01%).

A large part of the respondents were people aged over 50 (38.07%), and people between 41 and 50 years old (38.81%), which is consistent with the data on the average age of teachers in Poland (44.1 years) and in the European Union where two-thirds of teachers are over 40 years of age. In the range of 31–40 years, the respondents accounted for 19.64%, and 3.49% were 30 years and younger. The study area covered all voivodeships in Poland. Most numerously the survey questionnaires were completed by the respondents from Śląskie, Podkarpackie and Mazowieckie voivodships, and the least numerously from Lubuskie and Świętokrzyskie voivodships.

Research tools

Google forms were used to collect the data. The research tool was a questionnaire. Its questions concerned the impact of remote learning and work on health and its selected aspects, such as: physical health, mental health, physical activity and condition, and body mass:

1. How do you currently evaluate your health? Response categories: Very good, Good, Neither good nor bad, Bad.
2. In your opinion, has distance learning had an impact on your physical health? Response categories: Yes, positive – my physical health has improved, Yes, negative – my physical health has deteriorated, Don't know, No.
3. In your opinion, has distance learning had an impact on your mental health? Response categories: Yes, positive – my mental health has improved, Yes, negative – my mental health has deteriorated, Don't know, No.

4. If you feel a deterioration of your health, it particularly concerns:
   - aggravation of chronic diseases,
   - back pain,
   - joint pain,
   - abdominal pain,
   - migraines, acute headaches,
   - deterioration of vision,
   - heartburn,
   - gastric problems,
   - sleep problems,
   - other.
5. What degree of pain or physical discomfort have you experienced during the distance learning period? Response categories: I do not feel any, Slight, Moderate, Strong, Extremely strong.
6. During most of your remote learning days, have you been: Response categories: Full of life, Calm and composed, Happy, Stressed, Tired, Exhausted.
7. Has remote teaching had an impact on your daily activity and physical condition? Response categories: Yes, it is increased, Yes, it is decreased, No, it remains at a similar level.
8. Has your body mass changed during the distance learning period? Response categories: Yes, increased by more than 2.5 kg, Yes, increased 0.5 to 2.5 kg, Unchanged, Yes, decreased 0.5 to 2.5 kg, Yes, decreased more than 2.5 kg.

Statistical analysis of the results

The analysis of the results was made by gender. The significance of differences between the study groups was tested using the chi-square test. The Statistica ver. 13.3 program was used in the calculations.

Results

Every ninth respondent (11.35%) assessed their health as very good, more often those were men (5.17%). Most of the teachers described their health as good (56.15%). This answer, in turn, was chosen more often by women (4.91). A large proportion of the respondents could not determine their health condition (28.41%). Few (4.10%) assessed it as bad. The statistical data show that the subjective health condition is gender dependent ($x^2 = 10.51$ at $p = 0.05$) (Table 1).

Table 1. General assessment of teachers' health (percentage of respondents)

Answers to the question: How do you currently evaluate your health?	Total (N = 1,489)	Women (N = 760)	Men (N = 729)
Very good	11.35	8.82	13.99
Good	56.15	58.55	53.64
Neither good nor bad	28.41	28.68	28.12
Bad	4.10	3.95	4.25

Differences: women/men p = 0.05.

Almost half of the teachers believe that the change of active work mode to sedentary work with many hours of computer use in remote learning mode, has had a negative impact on their physical health and that it has worsened (49.33%). Very few respondents believe that this is a period when their physical health has improved (6.56%). One third of the surveyed group is unable to determine it (33.67%), and every tenth respondent believes that the period of remote learning has had no effect on their physical health (10.46%).

Defining the influence of distance learning on mental health, the most numerous group are the people claiming that remote work has had a negative impact on their psyche (53.39%). A minority believe that this has been a period when their mental health has improved (7.98%). Every fourth respondent could not define it (26.43%), and every eighth thinks that the period of remote learning has had no influence on their psyche (12.21%).

Based on the empirical analysis of statistical data, it was found that remote learning and its impact on physical health ($x^2 = 1.233$ at $p = 0.05$) and mental health ($x^2 = 1.116$ at $p = 0.05$) is gender independent (Table 2).

Table 2. The impact of remote work on physical and mental health as assessed by teachers (percentage of respondents)

	1. Answers to the question *Has distance learning had an impact on your physical health?*				2. Answers to the question *Has distance learning had an impact on your mental health?*			
	yes, positive – my physical health has improved	yes, negative – my physical health has declined	hard to say	no	yes, positive – my physical health has improved	yes, negative – my physical health has declined	hard to say	no
Total (N1 = 1,482 N2 = 1,491)	6.56	49.33	33.67	10.46	7.98	53.39	26.43	12.21
Women (N1 = 755 N2 = 759)	6.62	50.60	32.85	9.93	8.30	54.28	25.82	11.59
Men (N1 = 727 N2 = 732)	6.46	48.01	34.53	11.00	7.65	52.46	27.05	12.84

Differences: women/men $p = 0.05$.

The most common deterioration in physical health was related to back pain, visual impairment and sleep problems. Women indicated a greater degree of back problems, visual impairment and the occurrence of migraines. Men were more likely to notice gastric problems, heartburn, and joint pain. The perceived pain or physical discomfort was described by 50.58% as moderate, 22.99% as slight, 17.14% did not mention any pain, 8.53% as severe and 0.76% as extremely strong. When carrying out the empirical analysis of statistical data, it was found that the deterioration of health of the surveyed respondents during distance learning was dependent on the gender of the respondents ($x^2 = 46.94$, at $p = 0.05$) (Table 3).

Most of the respondents mentioned negative emotional states during remote work. Most teachers felt tired (53.18%) and stressed (29.94%). Women felt it stronger. Out of positive feelings and moods, nearly every third respondent felt calm and composed (29.97%). Men chose this answer much more often. Very few respondents felt full of life (2.48%) and happy (2.21%). Analysing the statistical data, it was found that the emotions of the respondents during distance learning were dependent on the gender of the respondents ($x^2 = 33.04$, at $p = 0.05$) (Table 4).

Table 3. The most common health problems caused by remote work (percentage of respondents)

Answers to the question: If you feel a deterioration of your health, it concerns	Total (N = 1,259)	Women (N = 657)	Men (N = 602)
Back pain	64.34	66.67	61.79
Deterioration of vision	57.82	63.62	51.50
Sleep problems	45.99	45.36	46.68
Joint pain	22.80	21.61	24.09
Migraines, acute headaches	21.05	26.64	14.95
Gastric problems	6.99	5.78	8.31
Heartburn	5.80	3.20	8.64
Aggravation of chronic diseases	4.69	4.72	4.65
Abdominal pain	4.69	4.72	4.65
Other	5.08	5.94	4.15

Differences: women/men p = 0.05.

Table 4. Experiencing positive and negative feelings and moods during the period of remote work (percentage of respondents)

Answers to the question: During most of the days within the distance learning period, did you feel	Total subjects (N = 1,493)	Women (N = 761)	Men (N = 732)
Full of life	2.48	1.84	3.14
Calm and composed	29.87	24.97	34.97
Happy	2.21	1.97	2.46
Stressed out	29.94	33.51	26.23
Tired	53.18	56.64	49.59
Exhausted	15.67	18.79	12.43

Differences: women/men p = 0.05:

When asked about the influence of distance learning on daily activity and physical condition, the vast majority believed that it had decreased (68.46%). More women than men replied in this way (by 6.13%). Over one fifth stated that their condition remained at a similar level (21.97%), and almost one in ten said that their condition had improved (9.57%). The period of remote work also had an impact on the body weight change of PE teachers. More than half of the respondents stated that their weight increased more than 2.5 kg in 20.62% and in the range from 0.5 to 2.5 kg in 36.39%. Every third respondent remained at the same body weight, and every tenth lost weight. Based on the empirical analysis of statistical data, it was found that the body weight of the respondents was gender dependent ($x^2 = 11.64$, with p = 0.05) (Table 5).

Table 5. Change in body weight during remote work (percentage of respondents)

Answers to the question: Has your body weight changed during the distance learning period?	Total (N = 1484)	Women (N = 759)	Men (N = 725)
Yes, increased above 2.5 kg	20.62	18.18	23.17
Yes, increased between 0.5 and 2.5 kg	36.39	37.68	35.03
Hasn't changed	33.36	34.91	31.72
Yes, decreased between 0.5 and 2.5 kg	6.13	6.72	5.52
Yes, decreased above 2.5 kg	3.50	2.50	4.55

Differences: women/men p = 0.05.

Discussion

The definition of health included in the constitutional act of the World Health Organization defines health as physical, mental and social well-being, and therefore something more than just an antonym of disease or infirmity (WHO, 1986). Therefore, health is a sense of life force, the ability to overcome obstacles, and the willingness to undertake physical and mental challenges. Three planes are distinguished in the cited definition of health. The first – physical or somatic health – related to the body, the second – mental health – determines consent and disagreement with oneself, the third – social health – is an opposition to those deviations that violate social norms. We can also distinguish two "dimensions" of health: individual and public health, as well as two "facets" of health: subjective and objective (Demel, 2002). The definition of health quoted above, along with the definition of its three planes, two dimensions and two facets, essentially corresponds to the content of the current work. The aim of this article is to present the results of the research on the state of physical and mental health, as well as everyday fitness and physical activity of a large group (N = 1498) of physical education teachers in the period of distance learning. The surveyed respondents come from all voivodeships in Poland and work in both primary and secondary schools. Therefore, the conducted research has a high representativeness factor and is the first study of this type on such a large scale in Poland.

Regarding the first research question (Has remote work had an impact on the physical and mental health of physical education teachers?), the study showed that changing the way of working had had an impact on the teachers' health. The subjective assessment of general health of the surveyed teachers at a very good and good level was 67.5%, and at a bad level – 4.10%. In similar studies, these values were respectively: 76.8% and 1.7% (Woynarowska-Sołdan, Węziak-Białowolska, 2012). Thus, compared to the surveyed group of teachers in Poland in 2012 (N = 750), the number of teachers describing their health as very good and good decreased by 9.3%, and the number assessing their health as bad increased by 2.4%.

A disturbing phenomenon is the fact that as many as 28.41% of the surveyed teachers were unable to determine their health condition using a very simple cafeteria of answers. Therefore, it can be concluded that these teachers have very low awareness of their own health, which is an undesirable phenomenon in the case of their professional and pedagogical roles in the context of health education.

When comparing the indicators, remote learning for almost half of the respondents (49.33%) had negative effects and in the opinion of these teachers their physical health deteriorated. It should be noted that the deterioration of their physical condition was most often related to: back pain (64.34%), deterioration of vision (57.82%), as well as problems with sleep (45.99%). At this point, it is worth presenting the results of the pre-pandemic research on the physical health of teachers conducted in many other countries. A cross-sectional study of the health of 3,679 teachers and 1,817 other education workers in France confirmed the significantly worse health of the study group of teachers. The greatest number of health problems concerned the nose inflammation, throat and bronchi, urinary tract infections, skin problems, conjunctivitis and varicose veins of the lower extremities (Kovess-Masféty, Sevilla-Dedieu, Rios-Seidel, Nerriè-re, Chan Chee, 2006). The analysis of subjective symptoms among 1,710 teachers in Hong Kong showed that as many as 99.5% of people reported at least one health problem. The most frequently indicated were voice (73.5%), eyesight (79.9%), shoulder pain (73.4%), neck pain (68.9%), problems with the lower spine (59.2%), headaches (67.1%), frequent colds (66.1%) and chronic fatigue (93.4%) (Chong, Chan, 2010). Comparative studies of teachers in Sweden showed neck pain that occurred in 44% of people, shoulder pain in 37% of the respondents, and pain in the lumbar region of the spine was reported by 36% of teachers (Arvidsson et al.,

2016). Research conducted in Malaysia on a group of 1,482 randomly selected teachers also confirmed a high percentage of pains in the lumbar spine – 48% of the people and in the neck – 60% of the people (Zamri, Moy, Hoe, 2017). In our query, however, no health research was found that covered only a group of physical education teachers, who are supposed to be more physically active on a daily basis than other pedagogical workers. Therefore, comparing the above data with the results of the study, it can only be concluded that major health problems related to back pain in the group of pedagogical workers had occurred earlier (Bortkiewicz, Szyjkowska, Siedlecka, Makowiec-Dąbrowska, Gadzicka, 2020), and remote learning could have worsened them, especially among physical education teachers. In addition, this study group reported problems with eyesight and sleep which appeared or intensified that can be explained by a large number of hours spent at the monitors while working remotely.

Based on the results of the conducted research, it was noticed that distance learning has a negative impact on the mental health of teachers. Such a correlation was indicated by 53.39% of people. The analysis of emotional states, divided into positive and negative, is particularly disturbing. Most of the respondents experienced negative emotional states during remote work. Most teachers felt tired (53.18%) and stressed (29.94%). Very few respondents felt "full of life" (2.48%) and "happy" (2.21%). Compared to the 2013 survey results, these two parameters dropped very significantly. At that time, the answers "full of life" were chosen by 59.0% and "happy" 65.7%, respectively (Woynarowska-Sołdan, Tabak, 2013). In pedeutological literature and in reports and studies on the health of education workers, there are many scientific dissertations dealing with the issues of mental health of teachers.

The main factors that caused stress in this occupational group in Poland before the pandemic period were: high organizational burden, work overload, dissatisfaction with social working conditions, including those related to the amount of remuneration (Pyżalski, 2008). The requirements set by educational authorities and continuous social evaluation can also contribute to the mental stress experienced by teachers (Garbacik, 2018). Such mental discomfort can lead to the burnout syndrome / complex, which was recognized as a public health problem as early as 2010. It is associated with serious health consequences for employees and a reduction in the efficiency and quality of work, resulting in high economic and social costs (Batista, Carlotto, Coutinho, Augusto, 2010). Stress that may be a consequence of the psychological burden in pedagogical work was also noticed and emphasized in studies conducted in Great Britain, New Zealand, Australia, Scotland and the United States.

Of all the surveyed in these countries, 30% said their profession was "stressful" or "very stressful" (Bortkiewicz et al., 2020; Pithers, Soden, 1998).

Based on the literature and conducted research, it can be concluded that the period of distance learning has been a big challenge for physical education teachers in Poland and caused the intensification of everyday work-related stress. Additionally, the need to learn and apply new tools in remote work increased the feeling of uncertainty. These factors, combined with reduced daily contact with students and reduced physical activity, have caused a permanent feeling of fatigue and stress in a large part of the respondents.

Referring to the second research question (Has remote teaching had an impact on the daily activity and physical condition of teachers?), it should be stated that the period of distance learning negatively affected the daily activity and physical condition. It decreased for 68.46% of the respondents. More women than men provided this answer, the difference is 6.13% of the respondents. The activity and physical fitness of teachers were also the subject of scientific research and publications by other authors. In the cohort California Teacher's Study on a sample of 329,684 female teachers working in the United States, it was confirmed that 30% of the respondents

did not undertake any form of physical activity, and the remaining persons performed various types of physical activity for an average of 4.2 hours a week (Bortkiewicz et al., 2020). The analysis of physical activity of teachers in secondary schools in Poland in 2011 showed that more men (36.6%) than women (14.9%) would undertake daily physical activity, while more women (53.2%) compared to men (29.3%) would spend their time actively several times a week (Prażmowska, Dziubak, Morawska, Stach, 2011). On the other hand, the results of the research on active recreation among PE teachers in Poland in 2012 indicated that this group of teachers spent an average of 7 hours on physical activity during the week. Most of the respondents (19.0%) exercised 10 hours a week, 14.0% exercised 5-6 hours a week, 2 hours (10.0%), and 12.0% of the respondents spent 4 hours actively (Lipowski, Szczepańska-Klunder, 2013). Additional research on physical activity among physical education teachers was carried out in 2018 (Ziemba, 2019). The conclusions of the empirical research were as follows: 26.7% of the respondents exercise twice or once a week, and 16.7% of the participants exercise daily. The preferred forms of exercise are: walking (46.7%), cycling (23.3%) and running (20%). Analysing the data obtained from the period of remote work and the frequency of undertaking pro-health behaviours before the pandemic, it should be concluded that it has had a negative impact on everyday physical activity and health-promoting behaviours undertaken by physical education teachers in Poland. Referring this to the Lalonde concept, the conditions necessary to maintain good health are not met (Lalonde, 1974).

Conclusion

The presented analysis of the results of cross-sectional research on the physical and mental health, fitness and physical activity of PE teachers in Poland in combination with the results of other studies in this area carried out in Poland, other European countries and worldwide justifies the complexity of the studied issues. The analysis has shown that remote learning has had a significant negative impact on the physical and mental health of the studied group. If the above-mentioned research results were far from satisfactory in the past, the period of the pandemic has only intensified the outlined doubts both in the individual and population spheres. The study of the impact of lockdown on physical activity and the subjective perception of health by physical education teachers in Poland suggests the following conclusions:

1. Based on the empirical analysis of statistical data, it was found that the influence of distance learning on physical and mental health is gender independent.
2. Based on the empirical analysis of statistical data, differences were found in the scope of the analysed factors depending on gender (physical ailments, emotional states, body weight).
3. Teachers more often negatively assessed their physical and mental health in comparison to studies from previous years.
4. The daily physical activity of the respondents decreased, and the majority of them increased their body weight.
5. Less than 3% of the surveyed teachers in the lockdown period felt happy and full of life, thus, the psychological discomfort felt by most may lead to the burnout syndrome.

The results of the research on the subjective health of physical education teachers in Poland provide new data on the health condition of this professional group. They can offer a certain basis for educational policy making and should be taken into account in planning the ongoing and prospective activities to improve the health of this study group, especially through:

1. Developing an action plan to support teachers in times of high psychosocial burdens of the COVID-19 pandemic.
2. Ensuring optimal conditions for remote work of physical education teachers by adjusting regulations, implementing modern work tools and providing appropriate training.
3. Conducting in-depth research on the physical and mental health of teachers taking into account the burnout syndrome.

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RELATIONSHIP AMONG SPORTS PARTICIPATION, SELF-PERCEPTION AND GENDER ROLE ORIENTATION OF ADOLESCENT FEMALE STUDENTS IN KWARA STATE, NIGERIA

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Abstract This study examined the relationship among sports participation, self-perception and gender role orientation of adolescent female students in Kwara State. Descriptive survey design was adopted for the study. 240 respondents were sampled from public secondary schools in Kwara State through simple random sampling technique; eight (8) public secondary schools were selected. Stratified and proportionate sampling techniques were used to select 20% of students by class. The research instrument was a self-structured close ended questionnaire. The data collection was conducted by the researcher and three (3) research assistants. Three null hypotheses were tested using Pearson's Product Moment Correlation (PPMC) statistic at 0.05 alpha level. The findings revealed no significant relationship between self-perception and sports participation, there was significant relationship between gender role orientation and sports participation. Also, there was significant relationship between social interaction and sports participation among the adolescent female students. The study recommends that the concept of sports should be promoted among the students while female students should be given equal opportunity in sports as their male counterpart. Also all students should be encouraged to participate in sports in order to promote social relationship with other students.

Key words: sports participation, self-perception, gender role orientation, female adolescents

Introduction

Background to the Study

Sports participation entails mental and physical involvement in competitive activities. Adolescence has different meanings to different people based on cultural, environmental and socioeconomic status. The period is usually accompanied by dramatic changes in the body, along with the developments in an individual's intellectual capacity. Adolescence therefore could be viewed as the transitional stage of development between childhood and full adulthood, representing the period during which a person is regarded as biologically an adult but emotionally not at full maturity.

Self-perception could be conceptualized as self-defined identity and perceived ability to protect or care for oneself. The concept could also be viewed as the process in which people, lacking initial attitudes or emotional responses develop them by observing their own behaviour and coming to conclusions as to what attitudes must

have driven that behavior (Fox, 2000). Harter (1999) stated that self-perception can also be domain-specific; this includes perceived intelligence, athletic competence, physical appearance, scholastic competence, and social acceptance. It has been further affirmed in literature that self-perception can be regarded as an overall rating of self-worth and that an individuals' sense of worth may vary depending on the environment (Harter, 1999).

Gender role orientation could be viewed as the culturally defined "attitudes, feelings, behaviour and motives associated with being male or female (Harrison, Lynch, 2005). Gender role orientation is a set of behaviour patterns, attitudes and personality characteristics stereo-typically perceived as masculine or feminine within culture. The concept also refers to an individual's understanding and acceptance of gender roles; that is how such an individual adapts prescribed sex role to his/her sex identity.

In early research (Theberge, 1993; Lantz, Schroder, 1999), gender role were defined along a single continuum of masculine or feminine, where being high on one trait implied being low on the other. According to Pederson and Kono (1990), the centrality of physique and bodily performance to athletic experience makes sport a particularly effective placing for the construction and affirmation of gender ideologies. Further, organized sport is absolutely a doubtlessly effective cultural arena for the perpetuation of the ideology of men's superiority and dominance (Messner, Duncan, Jensen, 1993).

Sports are still generally considered to be a masculine domain (Koivula, 1995). It is generally believed that boys outnumber girls in sports participation. One reason for this difference may have to do with gender role orientation; Mash (1998) contended that this difference tended to be consistent with traditional gender stereotypes. There are also views that individuals with a masculine gender role orientation might inhibit behaviours that are stereotyped as feminine, while in contrast those with feminine gender role orientation might inhibit behaviours that are stereotyped masculine. It may therefore be logical to assume that adolescent girls, who are more likely to hold feminine gender role orientation, may not engage in sports activities because sports are considered to be masculine activity.

Social interaction refers to a process by which human beings act and react in relation to each other. One vital aspect of social interaction is that the individual involved recognize every other person's underlying intention and meanings (Klomsten, Marsh, Skaalvik, 2005). Aside from motivating a healthy and fit lifestyle, socialization goals are also considered to be one of the factors that encourage individuals to engage in sport (Oliveira-Brochado, Brito Oliveira-Brochado, 2017).

Gould, Flett, and Lauer (2012) affirmed that sports and social skills are closely related. Particularly the sports that involve sharing the same environment with other people or that involve teamwork require social skills such as internalizing social norms, organizing behaviors according to rules, respecting others, initiating and sustaining publicity, communicating with others, cooperating with the group, taking responsibility and providing appropriate feedback. Sport participation improves interpersonal communication and is effective in sustaining participation in sporting activities (Ferguson, Shapiro, 2016).

Statement of the Problem

It is generally believed that boys take part more in sports compared to their female counterparts. Traditionally, girls are expected to assist their mothers more often in domestic work than participating in sport. The culturally formed identity and socially constructed inequality between male and female has so far made females to experience frequent segregation and discrimination in their access to sport participation, while this manifested into persistent stereotype at the expense of females. Lack of social support networking for sportswomen and girls who are willing

and showing potential capability poses a serious challenge to female sports participation today. Individual tends to see participation in sports as fun and an avenue to be in conformity with peers.

Finding has also provided that male adolescents are more active in sporting activity compared to female adolescents during their developmental years. This shows that there is a decrease in sport participation with an increase in age and especially among girls. This instance tends to limit their social interaction and creating unequal identity between female and their male counterpart. It is on this premise that the researcher is interested in investigating the relationship among sports participation self-perception and gender role orientation of female adolescent students in Kwara State.

Hypotheses

1. There is no significant relationship between self-perception and sports participation among female adolescent students in Kwara State.

2. There is no significant relationship between gender role orientation and sports participation among female adolescent students in Kwara State.

3. There is no significant relationship between social interaction and sports participation among female adolescent students in Kwara State.

Methods

The design adopted for this study was descriptive research of survey type. The population comprised all public secondary school students in Kwara State. Simple random sampling technique was used to select eight (8) public secondary schools representing 20% of the population; stratified sampling technique was used to select students from SS1, SS2, and SS3. The research instrument was a self-structured close ended questionnaire. The questionnaire has two sections; section A and section B. Section A dealt with the personal data and general information about the respondents while section B contained items eliciting information on variables under study. The modified Likert type four-point rating scale of SA – Strongly Agree, A – Agree, D – Disagree, and SD – Strongly Disagree was adopted.

The research instrument was validated by three (3) lecturers who are experts from the Department of Human Kinetics Education University of Ilorin. Test-re-test method was used to conduct the reliability of the instrument using Pearson's Product Moment Correlation (PPMC) statistic. The questionnaire was administered to the respondents by the researcher with the help of three (3) trained research assistants. The data collected was analyzed using descriptive statistics and inferential statistics. Hypotheses were tested using Pearson's Product-Moment Correlation (PPMC) statistic at 0.05 alpha level.

Statistical Analysis

Hypothesis 1. There is no significant relationship between self-perception and sports participation among female adolescent students in Kwara State.

Table 1. Descriptive statistics on relationship between self-perception and sports participation among female adolescent students in Kwara State

S/N	Items	Not at all	Somewhat unlike me	UF (%)	Somewhat like me	Verymuch like me	F (%)
1	I feel very happy with my body	58	43	42.1	17	112	57.9
2	I am glad that I look the way I looked	41	48	37.0	90	61	63.0
3	I am looking as nice as I would like to	34	61	39.6	61	84	60.4
4	I always curious about my achievement	40	56	40.0	80	64	60.0
5	I am excited about my academic performance	32	58	37.5	57	93	62.5
Column Total		205	266	471 (39.3%)	305	424 (60.7%)	729 1,200

Table 1 revealed that 60.7% of the respondents were favourable towards the items while 39.3% were unfavorable, this indicates that most of the respondents perceived there is relationship between self-perception and sports participation.

Table 2. PPMC showing relationship between self-perception and sports participation

	Variable	No	X	*df*
		r-value	*p-value*	*Decision*
Self-perception	240	4.06	0.71	H0
	239	0.16	0.13	Accepted
Sport Participation	240	3.03	0.91	

$P \leq 0.05$

Table 2 presents the correlation analysis on relationship between self-perception and sports participation. The mean value is 4.06 with standard deviation of 0.71, calculated r-value of 0.16 and p-value of 0.13 at 239 degree of freedom. The result implies that there is significant relationship between self-perception and sport participation among female adolescent students in Kwara State.

Hypothesis 2. There is no significant relationship between gender role orientation and sport participation among female adolescent students in Kwara state.

Table 3. Descriptive statistics on relationship between gender role orientation and sports participation among female adolescent students in Kwara State

S/N	Items	SA	A	F (%)	D	SD	UF (%)
1	Sport participation promotes gender equity	104	110	89.2	17	9	10.8
2	Engaging in sport decreased likelihood to breast cancer and osteoporosis in adulthood	84	119	84.6	29	8	15.4
3	Sport participation is associated with educational achievement among both male and female	67	126	80.4	31	16	19.6
4	Cultural background may hinder girls participation in sports due to cultural belief and religious belief	78	107	77.1	40	15	22.9
5	Participation in sports among female is lesser than male students	85	107	80.0	27	21	20.0
Column Total		418	569	987 (82.25%)	144	69 (17.75%)	213 1,200

Table 3 revealed that 82.25% of the response was favourable while 17.75% was unfavourable which shows there is relationship between gender role orientation and sports participation among female adolescent students in Kwara State.

Table 4. PPMC showing relationship between gender role orientation and sports participation

	Variable	No *r-value*	X *p-value*	*df* . *Decision*
Gender role orientation	240	2.35	0.62	H0
	239	0.22	0.01	Rejected
Sport participation	240	3.53	0.85	

$P \leq 0.05$.

Table 4 presents the correlation analysis on relationship between gender role orientation and sports participation. The calculated r-value was 0.22 and the p-value was 0.01 at 239 degree of freedom, the p-value was 0.01, therefore the null hypothesis is rejected. This implies that there is significant relationship between gender role orientation and sport participation among female adolescent students in Kwara State.

Hypothesis 3. There is no significant relationship between social interaction and sport participation among female adolescent students in Kwara State.

Table 5. Relationship between social interaction and sports participation among female adolescent students in Kwara State

S/N	Items	SA	A	F (%)	D	SD	UF (%)
1	Sport participation teaches and reinforces positive behaviors among the student	98	97	81.25	28	17	18.75
2	Sport participation develops social skills such as team work, leadership, sportsmanship and respect	87	99	77.50	38	16	22.50
3	Participation in sport increases sense of belonging and communication skills	87	103	79.20	33	17	20.20
4	Engaging in sport bring individual together and bridging cultural and ethnics divide	84	99	76.25	39	18	22.75
5	Sport participation develop positive characteristics such as stress management and ability to relate well with others	88	105	80.40	30	17	19.60
Column Total		444	503	947 (78.9%)	168	85 (21.1%)	253 1,200

Table 5 revealed that 78.9% of the response was favourable while 21.1% was unfavorable which shows that there is relationship between social interaction and sports participation among female adolescent students in Kwara State.

Table 6. PPMC showing relationship between social interaction and sports participation

	Variable	No	X	*df*
		.r-value	*p-value*	*Decision*
Social Interaction	240	4.52	0.81	H0
	239	0.29	0.00	Rejected
Sport Participation	240	3.71	0.90	

$p < 0.05$.

Table 6 presents correlation analysis on relationship between social interaction and sports participation. The calculated r-value was 0.29 and the p-value was 0.00 at 239 degree of freedom, p-value was 0.00, therefore the null hypothesis is rejected which means that there is significant relationship between social interaction and sport participation among female adolescent students in Kwara State.

Discussion

There was no significant relationship between self -perception and sport participation among female adolescent students in Kwara State. Though, research has indicated consistent Klomsten, Skaalvick, Espne, 2004) gender differences, with boys scoring higher on physical self-concept and self-esteem than girls; in recent years, there have been gradual changes in women's participation in sports, but the rate of changes has been found to be extremely low. Women have less free time in their choice of leisure activities and they are more restricted than males. Adeyanju (2011) noted that the low rate of women involvement in sports is not due to lack of interest in sports by them. Instead, it is due to the long history of direct and indirect forms of discrimination and stereo-typing that women have to contend with. Furthermore, identity theorists maintained that individuals pursue behaviours that are consistent with their gender identity (i.e., the degree to which they embrace masculinity and/or femininity) and avoid behaviours that violate the meanings associated with their gender identity (Adesoye, Obiyemi, Ibraheem, Ajibua, 2017).

Though, it is generally believed that expectations were the same for both genders. Female also perceived boys as skillful and aggressive. Sometimes, the behaviour of the male creates a physically or emotionally unsafe sporting environment for the female gender especially when events turn violent. McCormick, Frey, Lee, Gajic, Stamatovic-Gajic and Maksimovic (2009) affirmed that whether an individual will participate in sport or not is influenced by their perception. Negative self-perception or lack of required skills in sports may stop an individual from participating in sports and increase the avoidance of been seen in sports attire.

Also, there was significant relationship between gender role orientation and sports participation among the study population. Girls' participation in sports has been associated with family satisfaction. Furthermore, girls and women across countries are faced with a number of obstacles that can limit their interest and participation in sports, these barriers vary in terms of their complexity and can range from cultural stereotypes to decreased opportunities that result from cultural norms (Staurowsky, DeSousa, Ducher, 2009; Sabo, Veliz; 2008). For example, cultural stereotypes play a significant role in many countries including Nigeria thereby channeling girls and women into specific sports. These sports are often less culturally valued than the sports men typically play, resulting in fewer resources for female athletes, less prize money and lower salaries than men's sports (United Nations, 2007).

Furthermore, the finding revealed significant relationship between social interaction and sports participation. It has been affirmed that motivator for adolescents, and adults to play sports are for social interaction (Dionigi, Baker, Horton, 2011; Hargreaves, 1994). Socialization through sports facilitate strong relationships among age groups, not only do people have ample opportunity for interaction during sport participation, researchers have also found that playing sports can teach and reinforce positive social behaviors. Research has reported that parents have indicated that participating in sports helps children and adolescents develop important social skills such as teamwork, leadership, sportsmanship and respect. Furthermore, social interaction is improved through sporting activities; it also facilitates social harmony and social integration as sports programme may bring together students from a variety of background, social groups and with varying level of athletic ability, who are grouped together to work towards a common goal (Barnett, Weber, 2008; Forrester, Beggs, 2005).

Conclusion

The findings of the current study revealed no significant relationship between self-perception and sports participation among female adolescent students in Kwara State, Nigeria. The finding also reported significant relationship between gender role orientation and sports participation among female adolescent students. Lastly, there was significant relationship between social interaction and sports participation among adolescent female students in the study population. It is pertinent that sports specialists should groom female adolescent students to develop positive perception towards sports participation for them to showcase their potentials and reap the benefits of participation. Furthermore, parents and society in general should be enlightened to change orientation concerning female students' participation in sports. They should be encouraged to do away with cultural and traditional practices that hinder female participation in sports. Stakeholders in sports are also challenged to promote sports programme that will attract more females. The sports experts working with the female adolescent students should focus more on developing important social skills such as teamwork, leadership, sportsmanship and respect among these adolescents in order to promote social relationship with other students which could in turn facilitate increased participation.

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RELIABILITY OF THE COACH'S EYE GONIOMETER APPLICATION DURING SQUAT EXERCISE

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Abstract This study examined the test re-test, intrarater and interrater reliability of joint kinematics from the Coach's Eye smartphone application. Twenty-two males completed a 1-repetition maximum (1-RM) assessment followed by 2 identical sessions using 5 incremental loads (20, 40, 60, 80, 90% 1-RM). Peak flexion angles at the hip, knee, and ankle joints were assessed using 1 experienced practitioner and 1 inexperienced practitioner. The acceptable reliability thresholds were defined as intraclass correlation coefficient (ICC) $r > 0.70$ and coefficient of variation $CV \leq 10\%$. The test re-test reliability of peak hip and knee flexion were reliable across 20–90% 1-RM ($r > 0.64$; $CV < 4.2\%$), whereas peak ankle flexion was not reliable at any loaded condition ($r > 0.70$; $CV < 20.4\%$). No significant differences were detected between trials ($p > 0.11$). The intrarater reliability was near perfect ($r > 0.90$) except for peak ankle flexion ($r > 0.85$). The interrater reliability was nearly perfect ($r > 0.91$) except for hip flexion at 80% 1-RM and ankle flexion at 20% ($r > 0.77$). Concludingly, the Coach's Eye application can produce repeatable assessments of joint kinematics using either a single examiner or 2 examiners, regardless of experience level. The Coach's Eye can accurately monitor squat depth.

Key words range of motion, kinematics, lower limb joints, two-dimensional analysis, rehabilitation

Introduction

The back squat is a closed kinetic chain exercise requiring coordination at the hip, knee, and ankle (Schoenfeld, 2010). The back squat is commonly used by practitioners in rehabilitation and strength and conditioning (S&C) programs to assess an individual's neuromuscular control, strength, stability, and mobility within the kinetic chain (Escamilla et al., 1998; Hartmann et al., 2012; Myer, Paterno, Ford, Hewett, 2008; Wirth et al., 2016). The reliable and valid assessment of back squat mechanics provides useful information for S&C coaches and physical therapists regarding an individual's functional capacities or risk of injury. For instance, variation in squat depth is known to influence the development of kinetic and kinematic outcomes (Martinez-Cava, Moran-Navarro, Sanchez-Medina, Gonzalez-Badillo, Pallares, 2019; Rhea et al., 2016). While abnormal lower extremity kinematics during a deep squat may infer movement limitations stemming from mobility issues (Kim, Kwon, Park, Jeon, Weon, 2015; List, Gulay, Stoop, Lorenzetti, 2013; Macrum, Bell, Boling, Lewek, Padua, 2012). Attempts to monitor squat depth in sport science research have included practitioner observation, physical aids (e.g. bands, goniometers), and video analysis. However, the subjective nature of practitioner observation subjects this method to inter-rater variability, whereas physical aids can be challenging to replicate between studies. Further, the incorrect use of goniometers can affect its accuracy with respect to the location of bony landmarks, the estimation of the centre of rotation of the joint and the ability to locate and maintain the centre of the goniometer over this point (Gajdosik, Bohannon, 1987). Consequently, 3-dimensional (3D) motion-capture systems are relied upon as the "gold standard" to provide reliable and valid objective feedback. Nonetheless, the accuracy of 3D motion-capture systems comes at the extensive cost of time and resources which many practitioners do not possess.

With this background, cost effective 2-dimensional (2D) motion analysis systems are becoming an increasingly viable option in quantifying lower extremity kinematics (Olson, Chebny, Willson, Kernozek, Straker, 2011). While a plethora of 2D applications have been validated in physical therapy and clinical domains, most of the literature has investigated single joint movements or screening exercises (Keogh et al., 2019). The Coach's Eye is an affordable smartphone 2D motion-capture tool capable of providing joint kinematic feedback from a wide range of movement tasks via its touchscreen goniometer application. The Coach's Eye may provide useful objective feedback through the analysis of peak flexion angles at the hip, knee, and ankle joints. Surprisingly, while the Coach's Eye has been downloaded more than one million times (Mousavi et al., 2020), no study has examined all facets of the application's reliability.

Previous examinations of the Coach's Eye have displayed encouraging validity and reliability findings during treadmill running and wheelchair propulsion (Alkhateeb, Forrester, Daher, Martin, Alonazi, 2017; Mousavi et al., 2020). Though the relevance of these studies to complex movements such as the back squat are limited. In 2015, Krause et al. investigated the test re-test reliability and validity of kinematics during an unloaded squat pattern using the Coach's Eye against a 3D motion-capture system. Acceptable test re-test reliability at the hip (intraclass correlation coefficient [ICC] = 0.98), knee (ICC = 0.98), and ankle (ICC = 0.79) was reported. However, while the reporting of relative reliability statistics (i.e. ICC, r) is undoubtedly of importance, we wish to highlight a series of limitations. One, the omission of a paired samples t test and assessment of measurement error (i.e. coefficient of variation [CV]) prevents any worthwhile conclusions regarding the applications ability to detect meaningful change which isn't the result of measurement error. Another key absence is that of intrarater reliability analysis, which quantifies a single practitioner's self-consistency in scoring (Gwet, 2008). It is of material importance this is quantified because the accuracy of the Coach's Eye depends on the ability of the user to select specific video

frames and to draw joint angles via touchscreen (Keogh et al., 2019; Mills, 2015). Moreover, the application's interrater reliability, defined as the agreement between multiple examiners, is not yet known (Koo, Li, 2016).

Together, the issues of intrarater and interrater reliability of the Coach's Eye are imperative because coaches and clinician's decisions are often based on repeated measures by the same or by different examiners. Interestingly, other smartphone goniometer applications have displayed high intrarater and interrater reliability between experienced and inexperienced practitioners (Mehta, Bremer, Cyrus, Milligan, Oliashirazi, 2021; Milanese et al., 2014; Svensson et al., 2019), but it is inadvisable that the findings from one goniometer application should be used to infer the reliability of another. Given the aforementioned widespread use of the Coach's Eye it is reasonable to assume the application is being used by a population with a wide variety of kinematic knowledge; ranging from novice users to experienced users. Consequently, it is of material importance the interrater reliability between novice and expert users is assessed. No study has assessed the test re-test reliability, intrarater and interrater reliability of the Coach's Eye during back squat exercise. This warrants further investigation.

The primary objective of this study was to investigate the test re-test reliability of peak flexion angles of the hip, knee, and ankle joints from the Coach's Eye during back squat exercise. The secondary objective was to determine the intrarater reliability of measures using the same examiner, and the interrater reliability of measures between an experienced and inexperienced examiner. It was hypothesised the test re-test reliability, intrarater reliability, and interrater reliability of the Coach's Eye would be very high.

Methodology

Design

A repeated-measures within-subject design investigated the reliability of joint kinematics during the free-weight back squat. Each participant's back squat 1-repetition maximum (1-RM) was assessed, followed by 2 identical trials utilizing incremental loads of 20%, 40%, 60%, 80%, and 90% 1-RM. Participants were allowed to use their own lifting footwear.

Examiners

The first rater was the primary researcher who had 6 years' applied experience as a sports medicine practitioner. The second examiner was a postgraduate student with less than 1 years' applied experience as a sport scientist. Both examiners underwent a standardization session to familiarise themselves with the data collection methods prior to the study's commencement. Both examiners were blind to the other rater's measurements until all the data had been analysed.

Subjects

A total of 22 strength-trained male weightlifters (mean ± SD; age = 25.0 ±2.6 y; body mass = 90.7 ±14.0 kg; stature = 178.9 ±10.0 cm; back squat = 1-RM 175.7 ±29.2 kg; relative 1-RM = 2.0 ±0.4 x/body mass) were recruited for this study. All subjects had a minimum of 4 years' experience of resistance training and trained approximately 10.1 ±2.7 h per week. A sample size calculation was estimated using G*Power software (Version 3.1.9.3) (Faul, Erdfelder, Lang, Buchner, 2007). To the authors knowledge, no previous estimates of effect size (*ES*) have been established for the Coach's Eye. Twenty-two subjects were required to identify differences between 2 dependant

means using a Cohen's d_z of 0.63 (moderate effect), a 2-sided α level of 0.05 and a 1 – β of 0.80. Informed consent was provided prior to data collection with ethical approval granted by the St Mary's University ethics committee in accordance with the seventh revision of the Declaration of Helsinki (2013).

Facilities

Humidity (%) and temperature (°C) were monitored (Govee Thermometer Hygrometer H5075; Govee RGBIC, Los Angeles, CA). All sessions were performed at a similar time of day (±1 h) and were separated by 48–72 h. Subjects were instructed to refrain from strenuous exercise, and to avoid alcohol and caffeine consumption within 24 h of testing throughout the study duration.

Maximum strength assessment

The aims of the first session were to collect subject's anthropometric measures and to assess back squat 1-RM. Body mass (Seca 875; Seca GmbH & Co, Hamburg, Germany) and stature (Seca 202, Seca GmbH & Co, Hamburg, Germany) were recorded. Subjects performed a standardised warm-up protocol, which was used for all sessions. The warm-up consisted of 5 minutes cycling at 60 RPM and 60 W using an air-braked cycle ergometer (Wattbike Pro, Wattbike Ltd, Nottingham, UK) followed by 5 mobility exercises and 10 repetitions with an unloaded barbell. All repetitions were performed using a squat stand or power cage (Eleiko®, Halmstad, Sweden) in conjunction with a calibrated 20 kg barbell and bumper plates (Eleiko®, Halmstad, Sweden). The National Strength and Conditioning Association (NSCA) guidelines for assessing back squat 1-RM were adhered to (Haff, Triplett, 2016). Participants completed 5 repetitions at 50% of estimated 1-RM, 3 repetitions at 70% and 80% of estimated 1-RM, and finally, 90% of estimated 1-RM for a single repetition. As participants approached their estimated 1-RM, loads were increased by 1–10 kg in order to find a true 1-RM for each individual. A maximum of 5 1-RM attempts were allowed. If an attempt was unsuccessful, participants were allowed another attempt with a reduced load. Rest periods were 3 minutes between warm-up sets and up to 5 minutes between 1-RM attempts. Adequate squat depth was confirmed using video footage and observation from a sports medicine practitioner with 6 years' experience. Each subject's preferred feet placement was marked on the ground with a marker pen and white tape.

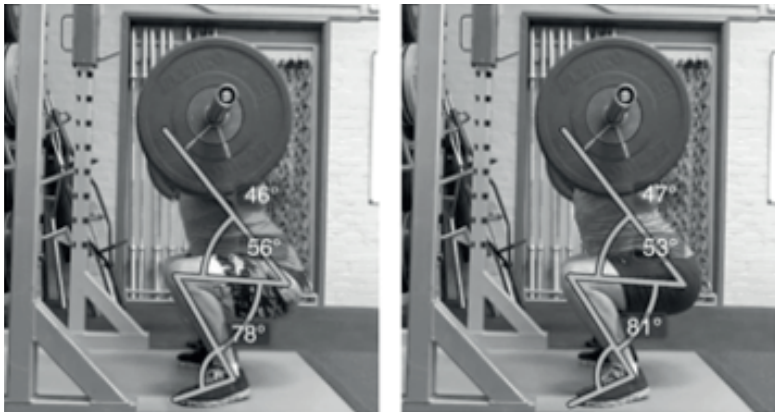
Joint kinematic assessment

Sessions 2 and 3 were identical; each requiring participants to perform 3 repetitions at 20, 40, 60 and 80% 1-RM and 2 repetitions at 90% 1-RM. Up to 3 minutes rest was provided between sets. All relative loads were rounded up to the nearest 1 kg. Participants were instructed to control the eccentric portion of the back squat at a self-selected pace until full knee flexion (>120.0°) was achieved (Bryanton, Kennedy, Carey, Chiu, 2012), followed by execution of the concentric portion until full hip and knee extension was achieved. Only the repetitions with the deepest squat depth at each loaded condition were analysed. Multiple repetitions were performed to ensure maximum depth was achieved.

Data acquisition

All footage was captured via a smartphone camera system (iPhone 11, version iOS 14.4.2; Apple, Cupertino, CA) utilising the Coach's Eye (TechSmith Corporation, USA, version 6.5.3.0) application at 60 fps and resolution of 1080 p. To minimise measurement error (Whiteley, 2015), the smartphone was rigged onto a tripod set at a height

of 62 cm (floor to camera) and distance of 250 cm (camera to centre of the lifting area) in the sagittal plane. The camera configuration was performed by the primary researcher throughout the study duration. Using the application's built-in feature, the video frame showing each subject's lowest portion of the squat at each relative intensity from both trials were displayed on the screen simultaneously (Figure 1). All linear angle markings were drawn via the built-in angle tool with the aid of a touch screen stylus (Mousavi et al., 2020). Markings were applied to anatomical regions previously described in the literature (Schurr, Marshall, Resch, Saliba, 2017): hip flexion was measured as the angle between the acromioclavicular joint and lateral knee joint with the greater trochanter serving as the fulcrum. Knee flexion was measured as the angle between the greater trochanter and lateral malleolus with the lateral knee joint serving as the fulcrum. Ankle dorsiflexion was measured as the angle between a line from the lateral knee joint through the lateral malleolus and a line parallel with the fifth metatarsal. To assess intrarater reliability a single practitioner performed the 2D analysis twice separated by a five-day period (Mousavi et al., 2020). While interrater reliability was determined through the comparison of both examiner's kinematic assessments from the first trial (Romero-Franco, Jiménez-Reyes, González-Hernández, Fernández-Domínguez, 2020).



A – trial 1 B – trial 2

Figure 1. Peak flexion angles at the hip, knee, and ankle captured using the Coach's Eye application

Statistical analysis

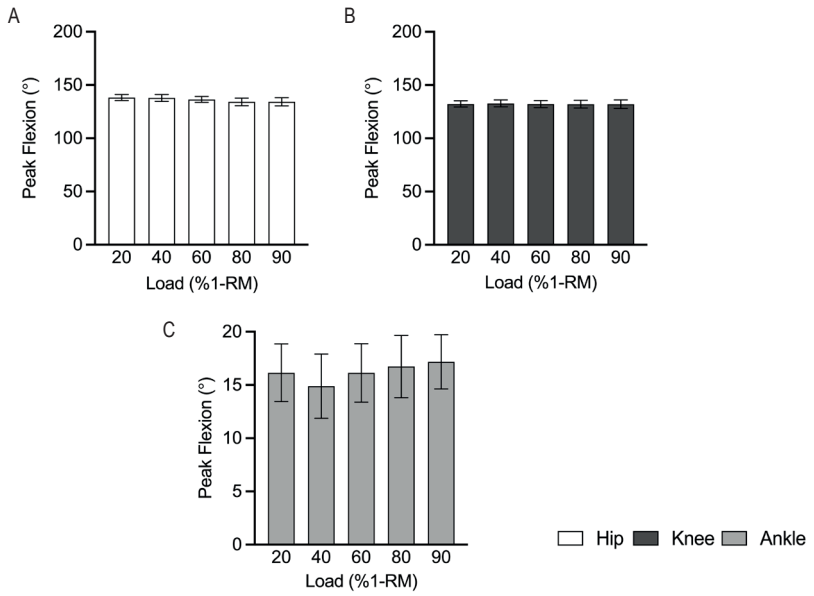
All measures were tested for normality using the Shapiro-Wilk test at an α level of 0.05. All data are presented as mean ± SD unless stated otherwise. Test re-test reliability of outcome measures from Coach's Eye application were assessed at each relative intensity against the magnitude of the correlation coefficient ($ICC_{3,1}$), CV, and *ES*. ICC was also used to determine the intrarater reliability ($ICC_{3,1}$) and interrater reliability ($ICC_{2,1}$) for the kinematic measures from the Coach's Eye (Shrout, Fleiss, 1979). The strength of the correlations were determined using the following criteria: trivial (0.00–0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), or nearly perfect (0.90–1.0) (Hopkins, Marshall, Batterham, Hanin, 2009). The magnitude of the CV were categorised as poor (>10%), moderate (5–10%), or good (<5%) (Duthie, Pyne, Hooper, 2003). The magnitude of the *ES* were considered trivial (<0.19), small (0.2–0.59), moderate (0.60–1.19), large (1.20–1.99), or very large

(>2.0) (Hopkins et al., 2009). This study considered the variables highly reliable if they met the following 3 criteria: very large correlation (>0.70) (Lachenbruch, Cohen, 1989), moderate CV (≤10%) (Atkinson, Nevill, 1998), and a small *ES* (<0.60) (Batterham, Hopkins, 2006). The standard error of the measurement (SEM) was also determined (Beckerman et al., 2001; Roebroeck, Harlaar, Lankhorst, 1993), which was used to calculate the minimal detectable change (MDC). The MDC was calculated using the formula (Schmitt, Di Fabio, 2004):

$$MDC = 1.96 \times SD\sqrt{2}\left(-ICC\right)$$

Significant differences of joint angles assessed by the first examiner between both trials were assessed using a 2-tailed paired samples t test with Bonferroni corrections and type 1 error rate set at $\alpha < 0.05$. The significant level was set at $p < 0.05$ and the confidence intervals (CI) for all analyses were set at 95%. The test re-test reliability were performed via a custom spreadsheet (Hopkins, 2015), whereas all other analyses were performed on SPSS (version 27.0: SPSS Inc, Chicago, IL).

Results



A – peak hip flexion; B – peak knee flexion; C – peak ankle flexion.
Error bars indicate SD. 1-RM indicates 1-repetition maximum.

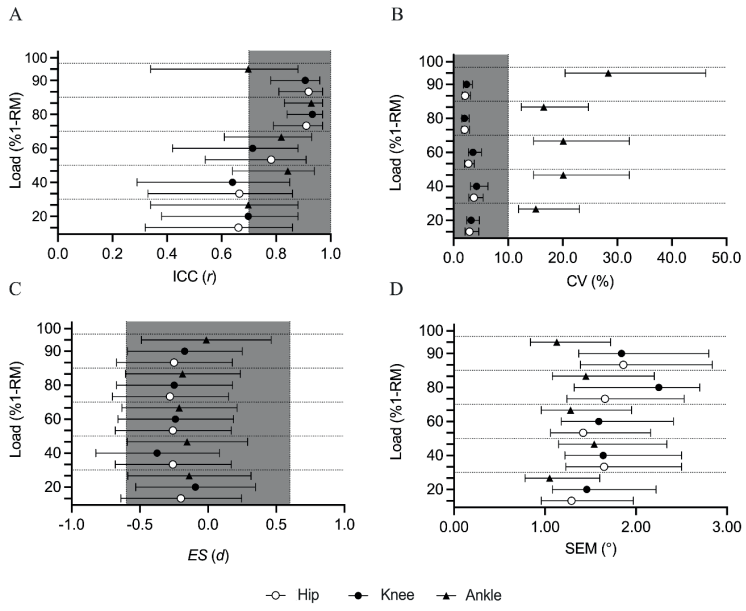
Figure 2. Group mean (SD) values from trials 1 and 2 for peak flexion angles at 20, 40, 60, 80, and 90% 1-RM load

Results from the Shapiro-Wilk test confirmed all measures were normally distributed ($p > 0.05$). No significant differences were found for temperature (trial 1: 14.4 ±3.7°C; trial 2: 14.9 ±4.5°C; $t_{21} = –1.00$, $p = 0.33$, $ES = –0.24$) and humidity (trial 1: 73.3 ±9.9%; trial 2: 72.5 ±8.9%; $t_{21} = 0.38$, $p = 0.71$, $ES = 0.82$) between trials. Figure 2 illustrates the overall mean flexion angles assessed by the first examiner. Group means of peak flexion angles between trials are presented in Table 1. No significant differences were detected between trials. The test re-test reliability results of peak flexion angles are shown in figure 3. Peak hip flexion was found to be reliable between 60–90% 1-RM. However, the ICC at 20 and 40% 1-RM did not meet the acceptable reliability threshold. Peak knee flexion was considered reliable at all relative intensities, except for 40% 1-RM, which displayed an ICC < 0.70. Peak ankle flexion was found to be unreliable across all relative intensities. This can be attributed to the poor CV. The intrarater and interrater reliability of peak flexion angles are shown in Table 2. The ICC of peak hip flexion at 20% 1-RM were very largely correlated between rater assessments. All other ICC were deemed to have nearly perfect correlations for peak hip (40–90% 1-RM), knee (20–90% 1-RM) and ankle (20–90% 1-RM) flexion between rater assessments. The interrater agreement displayed nearly perfect correlations across all joints and loaded conditions, with only 2 exceptions: hip flexion at 80% 1-RM and ankle flexion at 20% 1-RM which both showed very large correlations. The MDC of the outcome measures are shown in Table 3.

Table 1. Assessment of significant differences for peak flexion angles at the hip, knee and ankle joints between trials 1 and 2 at each relative intensity using the paired samples t test

Variable	Trial 1	Trial 2	t test[a]	p value
Peak hip flexion, mean ± SD, °				
20% 1-RM	136.6 ±5.4	137.7 ±6.8	–0.89	0.38
40% 1-RM	136.8 ±8.0	139.0 ±8.7	–1.41	0.18
60% 1-RM	136.0 ±6.7	137.2 ±7.5	–1.21	0.24
80% 1-RM	133.5 ±8.6	134.6 ±8.1	–1.31	0.21
90% 1-RM	133.7 ±9.4	134.7 ±9.3	–1.17	0.26
Peak knee flexion, mean ± SD, °				
20% 1-RM	131.0 ±7.3	131.6 ±7.20	–0.42	0.68
40% 1-RM	131.3 ±8.7	134.2 ±7.9	–1.67	0.11
60% 1-RM	131.3 ±8.6	132.8 ±7.2	–1.12	0.27
80% 1-RM	131.2 ±9.4	132.1 ±8.3	–1.16	0.26
90% 1-RM	131.4 ±9.9	132.1 ±8.4	–0.81	0.43
Peak ankle flexion, mean ± SD, °				
20% 1-RM	16.6 ±5.0	17.1 ±5.7	–0.60	0.55
40% 1-RM	14.6 ±8.0	15.2 ±7.8	–0.69	0.50
60% 1-RM	15.8 ±7.1	16.6 ±5.7	–0.99	0.33
80% 1-RM	16.5 ±6.9	17.1 ±7.6	–0.88	0.39
90% 1-RM	18.8 ±4.1	18.8 ±4.8	–0.05	0.96

Abbreviations: 1-RM – 1-repetition maximum.
[a] The degrees of freedom (*df*) = 21, unless otherwise stated.



A – ICC; B – CV; C – ES; D – SEM.
Gray-shaded area indicates the zone of acceptable reliability.
Error bars indicate 95% confidence limits. 1-RM indicates 1-repetition maximum; ICC – intraclass correlation coefficient; CV – coefficient of variation; ES – effect size; SEM – standard error of the measurement.

Figure 3. Forest plot displaying the test re-test reliability of peak flexion angles of the hip, knee, and ankle during the back squat at 20, 40, 60, 80, and 90% 1-RM load

Table 2. Intrarater and interrater reliability of joint kinematics[a]

Variable	Intrarater reliability		Interrater reliability[c]
	Trial 1	Trial 2	
	ICC[b] (95% CI)	ICC (95% CI)	ICC (95% CI)
1	2	3	4
Peak hip flexion °			
20% 1-RM	0.93 (0.82–0.96)†	0.94 (0.86–0.98)†	0.94 (0.84–0.98)†
40% 1-RM	0.91 (0.80–0.96)†	0.93 (0.83–0.97)†	0.94 (0.84–0.98)†
60% 1-RM	0.94 (0.85–0.99)†	0.93 (0.83–0.97)†	0.93 (0.83–0.97)†
80% 1-RM	0.97 (0.89–0.99)†	0.91 (0.80–0.96)†	0.79 (0.53–0.91)†
90% 1-RM	0.96 (0.90–0.98)†	0.95 (0.93–0.99)†	0.95 (0.87–0.98)†
Peak knee flexion °			
20% 1-RM	0.96 (0.89–0.98)†	0.93 (0.83–0.97)†	0.92 (0.80–0.097)†
40% 1-RM	0.97 (0.93–0.99)†	0.96 (0.90–0.98)†	0.96 (0.89–0.99)†
60% 1-RM	0.97 (0.93–0.99)†	0.96 (0.90–0.98)†	0.96 (0.89–0.098)†
80% 1-RM	0.97 (0.96–0.99)†	0.96 (0.90–0.98)†	0.98 (0.94–0.99)†
90% 1-RM	0.98 (0.96–1.00)†	0.95 (0.89–0.89)†	0.99 (0.98–1.00)†

1	2	3	4
Peak ankle flexion °			
20% 1-RM	0.85 (0.65–0.94)†	0.85 (0.66–0.94)†	0.77 (0.48–0.91)†
40% 1-RM	0.87 (0.72–0.95)†	0.92 (0.82–0.97)†	0.92 (0.80–0.97)†
60% 1-RM	0.97 (0.93–0.97)†	0.89 (0.76–0.95)†	0.92 (0.81–0.97)†
80% 1-RM	0.96 (0.92–0.99)†	0.90 (0.77–0.96)†	0.96 (0.90–0.98)†
90% 1-RM	0.94 (0.85–0.98)†	0.93 (0.83–0.97)†	0.91 (0.77–0.96)†

Abbreviation: ICC, intraclass correlation coefficient; CI, confidence interval.
[a] Analyses were restricted to participants without missing values.
[b] ICC are reported as mean at a 95% confidence interval.
[c] Interrater reliability assessed measurements between raters from trial 2.
† p values are significant at <0.001.

Table 3. Recommendations for the minimal detectable change of peak flexion angles at 20, 40, 60, 80 and 90% 1-RM

Load (% 1-RM)	Peak Hip Flexion °	Peak Knee Flexion °	Peak Ankle Flexion °
20	3.6	4.0	2.9[a]
40	4.6	4.5	4.3[a]
60	3.9	4.4	3.6[a]
80	4.6	4.9	4.0[a]
90	5.2	5.1	3.1[a]

Abbreviation: 1-RM – 1-repetition maximum; CV – coefficient of variation; *ES* – effect size; ICC – intraclass correlation coefficient.
[a] Did not meet reliability criteria (ICC > 0.70; CV ≤ 10% and *ES* < 0.60).

Discussion

This was the first study to assess the test re-test, intrarater and interrater reliability of peak flexion angles from the Coach's Eye during back-squat exercise. The primary findings affirm peak hip and knee flexion were reliable across 20–90% 1-RM, while peak ankle flexion was not reliable under any loaded condition. The secondary findings infer the Coach's Eye can produce repeatable assessments of joint kinematics using either a single examiner or 2 examiners, regardless of one's experience.

Joint kinematics remained stable across all loaded conditions. Of relevance, >120.0° of knee flexion was observed at each relative intensity, demonstrating a deep squat depth was achieved (Bryanton et al., 2012). Although supportive literature is limited, 1 study found peak flexion angles (hip = 127.2 ±15.5°; knee = 114.9 ±15.9°; ankle = 27.2 ±5.3°) captured through Coach's Eye are comparable to a 3D motion-capture system (Krause et al., 2015). Bland Altman analysis revealed large systematic bias at the hip (39.8° [–10.3° to –69.3°]), but acceptable bias at the knee (5.0° [–17.6° to 7.6°]), and ankle (3.1° [–14.6° to 8.3°]). Over estimations of hip range of motion highlight a limitation of 2D motion capture systems. This stems from the Coach's Eye's use of linear markers which are unable to account for lumbar-sacrum flexion around the pelvis (Norkin, White, 2009). Practitioners seeking to prioritise lumbar-sacrum assessments are advised to consider 3D kinematic tools (Chowdhury, Byrne, Zhou, Zhang, 2018; Eltoukhy et al., 2016). That aside, very large ICC between trials (Hip: ICC = 0.98; knee: ICC = 0.98; ankle: ICC = 0.79) were found, which coincide with our results. A novel discovery, however, was the high variation observed at the ankle joint across all loaded conditions. This may be explained by inter individual variances in ankle

dorsiflexion range of motion (Macrum et al., 2012), or type of footwear worn (Legg, Glaister, Cleather, Goodwin, 2017; Sinclair, McCarthy, Bentley, Hurst, Atkins, 2015). Regrettably, these were not accounted for. High variation may also be explained by the application of linear angles onto anatomical regions without the assistance of reflective markers. Although the absence of markers may be considered a time efficient advantage, this likely reduced the repeatability of measurements. For instance, previous investigations of alternate 2D kinematic systems have shown the assessment of ankle flexion is prone to more error than other joints (Mohammad, Elattar, Elsais, AlDajah, 2021; Romero-Franco et al., 2020). Nevertheless this study's excellent intrarater reliability suggests that joint kinematics are highly consistent when assessed by a single examiner, including at the ankle joint.

This study's intrarater reliability results concur with lower body assessments in the sagittal plane with comparable 2D motion-capture systems (Damsted, Nielsen, Larsen, 2015; Pipkin, Kotecki, Hetzel, Heiderscheit, 2016; Rabin, Einstein, Kozol, 2018). Similarly, our favourable interrater reliability findings are also concurrent with the literature (Mehta et al., 2021; Milanese et al., 2014; Svensson et al., 2019). An intriguing discovery, however, was the relatively lower ICC for ankle flexion at 20% 1-RM. While still acceptable, this too has been observed by Vohralik, Bowen, Burns, Hiller, and Nightingale (2015). It appears the literature's inconsistent reliability results for ankle flexion may simply reflect the lack of agreement between the examiners, rather than the (im)precision of a given goniometer application. In this regard, the Coach's Eye may share the same limitation as the standard goniometer in terms of the subjectivity of establishing body landmarks (Gajdosik, Bohannon, 1987). Nonetheless, this study found an inexperienced and experienced S&C coach can determine joint kinematics with very high agreement. Practitioners should be cognisant of the benefits and limitations of different goniometer applications and how this relates to their place of practice.

A curious finding was the low ICC for peak flexion at the hip and knee joint between trials at 20–40% of 1-RM. This can be explained by the homogeneity of the data observations between trials, which often displayed the exact same values. Such low variability within a sample is known to skew ICC variables (Koo, Li, 2016). This exposes the limitations of relying on a single metric for reliability analysis. Considering the trivial to small *ES* and good CV, peak hip and knee flexion can be considered to have acceptable reliability across 20–90% 1-RM. The MDC reported herein are a slight improvement on values reported by Krause et al. (2015). This may be explained by the video capture speed (60 fps) used in this study. Previous investigations captured footage at 30 fps which causes image blurring (Mills, 2015), and contributes to measurement error (Sheerin, Kendall, Ferber, 2009). Concludingly, considering changes in knee range of motion contribute most to squat depth in the sagittal plane ($r = 0.92$; $p < 0.001$) (Zawadka, Smolka, Skublewska-Paszkowska, Lukasik, Gawda 2020), peak knee flexion from the Coach's Eye may be used to assess squat depth. Given that knee range of motion assessment is prevalent in therapeutic literature (Milanese et al., 2014), the Coach's Eye may be useful in clinical practice. Future research may wish to assess the feasibility of the Coach's Eye, or similar goniometer applications (Weiler, 2016; Vercelli, Sartorio, Bravini, Ferriero, 2017), against 3D kinematic systems using a wider range of rehabilitation exercises (Comfort, Jones, Smith, Herrington, 2015).

Practical implications

The present study shows that peak knee flexion from the Coach's Eye can be used to accurately monitor squat depth using 2 examiners, regardless of experience. To ensure consistency, the equipment setup must be identical between sessions. Further, to aid the validity of longitudinal monitoring the same app and camera system

should be used where possible. Because these findings are limited to healthy individuals with no pathologies further research is required to determine whether the Coach's Eye's is a feasible clinical tool for physical therapists. Finally, future studies may also with to determine the validity and reliability of the Coach's Eye during single leg screening exercises or dynamic range of motion tasks (Keogh et al., 2019).

Conclusions

The present study elucidates the Coach's Eye can be used to monitor squat depth in the sagittal plane using multiple examiners with different levels of experience in the full depth back squat using strength-trained males. Caution is advised when using goniometer applications to assess ankle range of motion.

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COLD WATER IMMERSION AS A METHOD SUPPORTING POST-EXERCISE RECOVERY

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[A] Study Design; [B] Data Collection; [C] Statistical analysis; [D] Manuscript Preparation; [E] Funds Collection

Abstract The aim of the study was to assess the effect of cold water immersion on changes in blood lactate concentration during post-exercise recovery in swimmers subjected to2-minute exercise test (front crawl swimming movements) using a VASA Swim Ergometer, with the maximum arm speed movements, as during the freestyle technique. The study covered 11 professional swimmers of the MKP Szczecin club, tested twice with a two-week interval. Each participant performed an exercise test twice, once with a passive recovery period, and the second time with cold water immersion after exercise, as a method potentially supporting the post-exercise recovery process. Each time before the test, immediately after and at 3, 6 and 9 minutes after exercise, the concentration of lactate in the capillary blood was measured. Statistical analysis of the obtained results showed that cold water immersion applied immediately after exercise resulted in a faster reduction of lactate concentration. The conducted research confirms that cold water immersion used in post-exercise recovery may be an effective method of restoring optimal physical fitness as part of the training process.

Key words exercise recovery, cold water immersion, lactate concentration

Introduction

Sports competition is very often characterized by intermittent bouts of high-intensity activity, separated by short bouts of low-intensity activity. Physical exercise, depending on its nature and duration, can be classified as aerobic, anaerobic or, in most cases, of a mixed nature. The basis for the metabolic classification of physical exercise is the participation and metabolism of individual energy substrates in the acquisition of ATP during the process. Working in aerobic conditions, thanks to the balance between oxygen demand and uptake, allows the oxidation of glucose to pyruvate, then acetylocoenzyme A (acetyl-Co-A) used in the citric acid cycle without lactate accumulation. Anaerobic energy production is important in maintaining high-intensity work efficiency when the

ATP requirement is greater than the oxygen trail can provide. With the dominance of the anaerobic component, the pyruvate is reduced to lactate with the participation of nicotinamide adenine dinucleotide (NADH). This reaction is catalyzed by the enzyme lactate dehydrogenase. The anaerobic lactate is transported from the skeletal muscles to the liver and kidneys, where it is converted back into glucose. The concentration of lactic acid in the body depends on the rate of its production and the speed of its utilization. The skeletal muscles, liver, heart muscle and kidneys are mainly responsible for the lactate removal process (Klusiewicz, Zdanowicz, 2002). Among the measurements used to assess the physiological exercise tolerance and the effectiveness of the post-exercise recovery process in athletes at various levels of training, the blood lactate concentration is most often assessed at various intensities of exercise (von Duvillard, 2001). There are several hypotheses explaining the mechanism of the formation of lactic acid in the muscles during physical exercise. The main ones are oxygen deficiency hypoxia; β- adrenergic stimulation of glycogenolysis by adrenaline (Klusiewicz, Zdanowicz, 2002). If physical exercise is characterized by high intensity, lactic acid will accumulate as a result of exceeding the lactate threshold, with increased recruitment of motor units with higher excitability and increased activation of glycolysis (Astorino et al., 2019). This will contribute to the occurrence of the phenomenon of muscle fatigue, which is defined as the inability of the neuromuscular system to generate energy around the joint (Rodacki, Fowler, Bennett, 2002). Short-term impairment of neuromuscular fitness may be a result of several factors, including inhibition of muscle contractions as a result of the accumulation of metabolic end products such as lactate in the muscle (Maté-Muñoz et al., 2017), a subsequent increase in the concentration of hydrogen ions in the cytoplasm of muscle cells, which in turn reduces the ability to contract (Klusiewicz, Zdanowicz, 2002; McCully, Authier, Olive, Clark, 2002; Cairns, 2006). Currently, the very high sports level of participants resulting from the intense training load and the maximum use of the body's exercise capacity forces the coaches and swimmers to search for effective methods to improve the process of post-exercise recovery, in order to accelerate the readiness to take further loads, one of them being cold water immersion (CWI). Although this method has been used in sport for a long time, there is still a lack of data unambiguously assessing its effectiveness, the more so as it was often combined with an initial active recovery. Based on the meta-analysis from 2011, it is postulated today that CWI alleviated symptoms of DOMS at 24, 48, 72 and 96h post exercise; had a small but significant effect in reducing efflux of CK post-exercise and had no effect on recovery of muscle strength but was effective in improving recovery of muscle power (Leeder, 2011), but research outlining the efficacy of CWI facilitating recovery of muscle function seems to vary, based on the type of exercise mode used or participants of various sports disciplines. As such, the effect of CWI alone on performance and physiological recovery remains unknown. Considering that this is a strongly stimulating method, it is justified to conduct research in this area.

Materials and methods

The study included 11 professional swimmers aged 18 to 23 from the MKP Szczecin club. The study was also approved by the local Ethics Committee (Ethics Committee of the Pomeranian Medical University; Ref. No. KB-0012/36/13). The research was carried out in two stages, two weeks apart. In the first stage of the research, the participants completed a questionnaire, from which information was obtained on age, gender, length of their swimming experience, swimming style and training load. The youngest participant was 18 years old and the oldest 23 years old. The mean age of the whole group was 18.81 years (±1.72). Individual measurements of height and weight were taken for each participant. Based on anthropometric data, the following indices were calculated: BMI

(Body Mass Index) using the formula: body weight[kg]/height[m]^2. The crawl swimming style dominated, as many as 8 out of 11 participants chose this style as preferred in everyday training. The remaining 3 participants indicated breaststroke, backstroke, or butterfly swimming style. The shortest swimming experience was 11 years and included 3 years of amateur swimming and 8 years of professional swimming, including participation in international competitions. The longest experience amongst the studied group was 16 years and included 4 years of amateur swimming and 12 years of professional swimming, including participation in the Summer Olympics. Subsequently, the procedures related directly to the planned exercise test were initiated. Each participant was subjected to a fingertip resting capillary blood lactate measurement taken using a lactic acid analyzer, which uses an enzymatic-amperometric determination of capillary lactic acid concentration as a measurement. Then the participant began a two-minute resistance exercise test on a Swim Bench Ergometer (Vasa Inc., Essex Junction, VT, USA). Figure 1 shows the position of the swimmers during the test. The Swim Bench swimming trainer reproduces the movements performed during training in the water. The use of the ergonometer is based on its excellent movement reproducibility, as evidenced by the optimal correlation between the results of tests on the ergonometer and during swimming at distances of 25, 50, 100, 200 and 400 m. Even if the exercises performed on the ergonometer show biomechanical and physiological differences from the actual swimming practices (Guilherme, Guglielmo, Denadai, 2000).

Figure 1. Resistance exercise test on a Swim Bench Ergometer

The duration of the exercise test, during which the swimmers had to maintain maximum arm speed using freestyle technique, was 2 minutes for each swimmer and the athlete's task was to maintain the maximum intensity (frequency) of swimming movements throughout the exercise test. Such assumptions correspond to the efforts made during the 200 m freestyle competition in which the swimmers partake most often. The ergometer was calibrated before each subsequent test. During the test, the muscles of the upper limbs, chest and back muscles were involved. The lower limbs did not play a significant role during the exercise, because their movement was limited by the bench on which the participant was lying. The total work performed by the participants was assessed each time [W]. Following the exercise test, the concentration of lactate was measured at the following time points: immediately after exercise and to assess post-exercise recovery at 3, 6 and 9 minutes since finishing the exercise test.

Stage II of the research

There was a two-week break between the research stages. The procedures carried out in the second stage of the research were identical to the first stage, except for the use of cold water immersion immediately after the physical exercise amongst all participants.

Cold water immersion procedures (CWI)

The immersion in cold water (9°C ±1°C) was applied once and individually for each of the participants immediately after their post-exercise lactate concentration was measured. During the procedure, participants wore shorts only. The start time of the CWI was monitored from the moment the participant assumed a seated position in the bathtub. The submersion to the neck level lasted 3 minutes, during which no movements were performed. The water temperature was monitored after each treatment and, if necessary, it was adjusted to the correct temperature by adding ice cubes. After the procedure, consecutive measurements of lactate concentration were taken for each of the researched participants.

Statistical analysis

Statistical calculations were made with the use of the Statistica 13.3 software (Statistica 13 PL, StatSoft). The distribution of results was tested using the Shapiro-Wilk test. As the features of the normal distribution were confirmed, the characteristics of the analyzed variables were presented as arithmetic means and standard deviation. The analysis of variance and the Tukey's HSD and Newman-Keuls post-hoc tests were used to assess the changes in lactate concentration over time. The p value < 0.05 was considered statistically significant.

Results

The anthropometric characteristics of the study group has been presented in Table 1. The mean value of BMI in the tested swimmers was 22.05 ±1.28 (ranging from 18.72 to 23.22 kg/m²). A summary of individual results of work performed on the Swim Bench swimming ergometer for I and II stage is presented in Tables 2 and 3. To standardise the load of physical exercise, the same resistance and duration of exercise were used for all participants. In the first stage, the athletes performed at the average value of 157.27 (±2.28) W. The lowest result was 154 W, and the highest was 161 W. The second exercise test took place two weeks later, and the same training load and the duration of exercise was used on a swimming ergonometer, with an additional CWI procedure post-exercise. The average value of the work was comparable with the value obtained during the first stage of the research, and amounted to 157.36 (±2.01) W. The lowest value obtained was 154 W, and the highest 161 W.

Table 1. Anthropometric characteristics of the participants

n = 11	Mean value	Minimum	Maximum
AGE (years)	18.82 ±1.72	18	23
BODY MASS (kg)	71.71 ±6.68	62	80
BODY HEIGHT (m)	1.81 ±0.07	1.67	1.88
BMI (kg/m^2)	22.05 ±1.28	18.72	23.22

BMI – Body Mass Index.

Table 2. Individual values of lactate concentrations in the I stage of research

No	Swim bench			Lactic acid measurement				
	Resistance (MET)	Work rate (W)	Time (min)	Pre (mmol/l)	Post (mmol/l)	3 post	6 post	9 post
1	5	158	2	1.9	12.7	9.9	6.1	5.2
2	5	157	2	1.7	13.4	8.7	7.9	7.3
3	5	155	2	1.7	11.8	11.7	11.1	10.9
4	5	155	2	1.5	11.6	9.6	11.7	10.9
5	5	160	2	1.5	12.1	10.9	7.8	7.3
6	5	154	2	1.6	12.4	9.9	9.5	9.1
7	5	161	2	1.5	11.3	7.2	6.8	5.4
8	5	157	2	1.9	12.1	10.6	11.2	9.3
9	5	160	2	1.9	12.6	5.7	6.1	5.2
10	5	157	2	1.8	11.5	4.8	4.8	2.9
11	5	156	2	1.8	11.9	7.0	7.0	6.1
X	5	157.27	2	1.71	12.13	8.73	8.18	7.24
±SD	±0	±2.28	±0	±0.16	±0.61	±2.25	±2.35	±2.58

Table 3. Individual values of lactate concentrations in the II stage of research

No	Swim bench			Lactic acid measurement Bathtub						
	resistance (MET)	work rate (W)	time (min)	pre (mmol/l)	post (mmol/l)	3 post (min)	6 post (min)	9 post (min)	water temp. (°c)	duration (min)
1	5	157	2	1.8	12.8	6.2	4.4	4.3	9	1
2	5	155	2	1.5	13.0	5.9	4.4	4.2	9	1
3	5	155	2	1.6	12.3	5.0	4.9	3.9	9	1
4	5	161	2	1.7	12.0	4.6	4.6	3.8	9	1
5	5	158	2	1.7	12.3	4.8	4.4	3.9	9	1
6	5	156	2	1.9	12.5	5.9	5.5	3.8	9	1
7	5	158	2	1.4	11.3	3.9	3.2	2.3	9	1
8	5	160	2	1.9	12.2	5.9	6.1	5.6	9	1
9	5	159	2	1.7	12.3	3.9	5.0	3.9	9	1
10	5	156	2	1.8	11.6	2.7	2.4	2.4	9	1
11	5	156	2	1.7	11.9	5.0	5.1	5.0	9	1
X	5	157.36	2	1.7	12.2	4.89	4.55	3.92	9	1
±SD	±0	±2.01	±0	±0.15	±0.49	±1.08	±1.02	±0.96	±0	±0

The first resting measurement of the concentration of lactate in the capillary blood (mmol/l) was taken from each participant immediately before starting the exercise test. The mean values at rest were similar, not significantly different between the study stages, amounting to 1.84 ±0.43 mmol/l and 1.55 ±0.61 mmol/l, respectively. Further measurements were made immediately after and at 3, 6 and 9 minutes after the end of exercise, while in the second

stage, between the measurement immediately after exercise and at 3 minutes, a one-minute cold water immersion was applied.

There was a significant difference in post-exercise lactic acid concentration values between stages. The use of CWI as a form of post-exercise recovery significantly influenced the rate of lactic acid metabolism in the blood after the training session. The highest statistical significance in the measurements of the concentration of lactic acid in capillary blood was recorded 6 minutes after the end of the CWI procedure (p = 0.0004065).

Figure 2 shows a comparative dynamic of changes in lactate concentrations at individual measurement points for both stages of the study. The significance level of the differences between the concentrations of lactic acid in the subsequent minutes of post-workout regeneration in relation to the baseline values in the first (passive recovery) and second (cold water immersion) stage of the research is presented in Table 4.

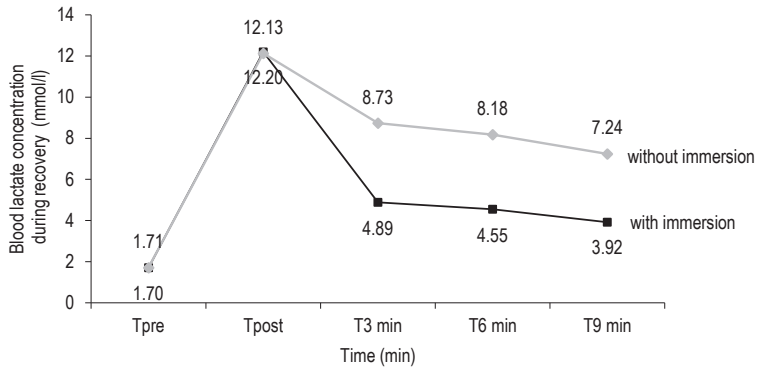

Figure 2. Dynamic of changes in lactic acid concentrations during the exercise test in the first and second stage of the tests, for all participants

Table 4. The level of significance of differences between the concentrations of lactic acid in the consecutive minutes of post-exercise recovery in relation to the resting values in the first stage (passive recovery) and the second stage of the research (cold water immersion)

Pre vs. 3 min	Pre vs. 6 min	Pre vs. 9 min
	Passive recovery	
p = 0.08729	p = 0.0004065	p = 0.001531
	Recovery with CWI	
p = 0.7972	p =0.00717	p =0.2001

Discussion

Biological renewal using natural or artificial stimuli shows a comprehensive systemic effect in post-exercise recovery. Physiotherapeutic treatments play an important role in this process because they do not only optimize

recovery processes, but also prevent the occurrence of overload diseases and support faster return of injured athletes to sports training.

Among the physiotherapeutic treatments used, hydrotherapy methods are widely used in post-exercise recovery of the body, including sauna, full and partial baths, and all methods in the field of thermotherapy. Depending on the stimulus used, hydrotherapy can contribute to both calming and stimulating the body, reducing muscle and joint pain, has a hardening effect, affects muscle tone, and often improves well-being. Using the acquired knowledge, we can intervene more precisely in the process of rest and recovery, however, any intervention should be applied in accordance with the current knowledge in the field of exercise physiology, psychology, and training technology, based on evidence-based treatment (Jonak, Skrzek, 2009).

Training has an adaptive effect on the cardio-respiratory and neuromuscular systems, thus increasing the amount of oxygen supplied to the mitochondria, as well as it enables more precise regulation of muscle metabolism (Jones, Carter, 2000). However, intense, and prolonged effort with time-limited recovery may lead to the phenomenon of overtraining and, consequently, increasing the athlete's susceptibility to injuries. During training, mechanical and/or metabolic loads arise (White, Wells, 2013). High-intensity training leads to local inflammation (Roberts at el., 2015), which in the absence of full recovery before subsequent training sessions over a longer period of the training cycle may translate into secondary tissue damage, the occurrence of pain and a reduction in physical, as well as mental work efficiency (White, Caterini, 2017). Research by White and Wells shows a link between exercise and intense training and elevated levels of reactive oxygen species (ROS) in the body. Chronic high levels of ROS in relation to the antioxidant capacity of the system may result in impairment of the ability to generate strength, which in turn translates into a deterioration of sports performance (White, Wells, 2013). Due to the risk of overtraining, it is important to search for and use methods that allow you to monitor athlete's fatigue in a non-invasive way. However, this is a complicated task as fatigue is a phenomenon that is characterized by not only physical but also psychological factors. If the respiratory and cardiovascular systems cover the body's need for oxygen, breathing with a predominance of the oxygen component is the primary means of converting nutrients into the necessary energy. However, when oxygen supply is no longer maintained or less efficient, anaerobic glycolysis dominates the mode of energy production. During this process, lactic acid builds up in the working muscle cells. Hydrogen ions contribute to lowering the pH of the interstitial fluid, which in turn reduces the speed of propagation of the potential activity along the muscle fibers. Therefore, it is common to monitor blood lactate levels and the rate of oxygen consumption (VO_2) during exercise (Ražanskas, Verikas, Olsson, Viberg, 2015).

To minimize the risk of overtraining, it is not necessary only to choose an appropriate training regimen, provide sufficient time for the recovery of the body, but most importantly to accelerate the return of post-exercise recovery. For this purpose, biological regeneration methods are more and more commonly used. Properly selected regenerative therapy not only has a chance to reduce overload and fatigue resulting from training, but also prepare the athlete's body for further loads (Jonak, Skrzek, 2009). In recent years, there has been an increase in the quantity of research focusing on CWI, yet findings remain unclear. The regenerative effects during the use of CWI occur mainly based on the mechanical effect of hydrostatic pressure, the reduction of body surface temperature with subsequent hyperemia (Yeungat at el., 2016), but also the reduction of inflammation and edema (Aguiar at el., 2016). Studies by Bleakey et al. And Leeder et al. show that CWI can affect blood flow through the mechanisms of vasoconstriction and vasodilation, largely dependent on the water temperature (Bleakley et al., 2016; Leeder, Gisanne, van Someren, Gregson, Howatson, 2012). It is also believed that cold water immersion may reduce nerve

conduction (Algafly, George, 2007), resulting in pain reduction in the Delayed Muscle Pain Syndrome (DOMS). The general effect of CWI is based on the ability to alleviate post-exercise hyperthermia, remove accumulated metabolic products, including lactic acid, alleviate subsequent changes in the central nervous system (CNS), reduce exercise-induced muscle damage (EIMD) and improve the functioning of the autonomic nervous system (Ihsan, Wattson, Abbiss, 2016).

In our study, the temperature of 9 ±1ºC was used for 1 minute immediately after exercise. The temperature was chosen based on previous reports regarding the effect of cold water immersion on recovery from exercise-induced muscle damage, in which it was considered unjustified to lower the temperature to a value below 10 degrees, both due to the comfort of the treatment and its effect (A. Vieira, at el., 2016). As for the duration of immersion, the literature data vary, depending on the parameters assessed (Elias at el., 2012; Poppendieck, Faude, Wegmann, Meyer, 2013). Our research seems to be particularly relevant in the short-term context, for example between startup recovery. The effect of CWI is not limited to the effect related to faster reduction of lactic acid concentration. CWI is effective in alleviating DOMS up to 96h post exercise, especially following high intensity exercise as well as in improving rate of recovery of muscle power post exercise (Leeder, 2011).

Also, research on the effects of CWI conducted by Kich proved the positive effect of CWI treatments on reducing DOMS ailments in cyclists (Kich, Krymski, Michalik, Kawczyński, 2018). Similarly, Adamczyk et al. confirmed the effect of CWI on the accelerated reduction of lactic acid concentration and the reduction of pain in DOMS (Adamczyk, Krasowska, Boguszewski, Reaburn, 2017). Scientific research has also shown that CWI affects the body's post-training response, contributing to the reduction of testosterone and cytokines levels; in particular IL-6 (Earp, Hatfield, Sherman, Lee, Kraemer, 2019). Additionally, evidence to date suggests that CWI reduces skin temperature and through the vasoconstriction and dilation may lead to changes in blood flow and reduction in swelling, inflammation, and muscle spasm (Peiffer, Abbiss, Watson, Nosaka, Laursen, 2010; Vaile at al., 2010), reduces the inflammatory response and minimizes secondary muscle damage responses (Knight, Brucker, Stoneman, Rubley, 2000).

Currently, sports medicine is developing very intensively. World records in individual disciplines are being improved increasingly more often, however, to achieve this level, athletes must undergo exhausting and long-lasting training sessions that negatively affect their health, both physical and mental, causing overtraining and increasing the risk of injury. That is why it is so important that the field of biological recovery is constantly developing. This will contribute to faster recovery and reduce the risk of undesirable training effects (Złotkowska at el., 2015).

Conclusion

The study has analyzed the issue of physical load on the body and the assessment of the possibility of accelerating the elimination of post-exercise homeostasis disorders, assessed by the concentration of lactate in the capillary blood, supported by the cold water immersion. The major finding of this investigation was that acute application of cold-water immersion after exercise was more effective than passive recovery according to post-exercise lactation treatment. In addition, in the subjective assessment of the participants in the study, the procedure of such a short duration was well tolerated and could be included in the methods of exercise recovery, especially in the starting period.

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OBESITY, PHYSICAL ACTIVITY AND PROSTATE CANCER: AN OVERVIEW

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Abstract Obesity and a lack of sufficient physical activity (PA) are recognized as risk factors for most civilization diseases, including cancer. This study synthesized the current evidence evaluating the relationship between excess body weight and prostate cancer (PCa) in the relation to the disease risk, progression, and mortality, and identifies biological plausibility of the association. We also estimated the importance of PA in intentional body weight loss.

Several electronic major databases to identify eligible articles were searched until March 2022. A total 22 observational articles, the literature on the underlying biological mechanisms, and the crucial evidence of a role of PA in body weight maintenance and reduction were reviewed.

The available knowledge suggests that association between body mass index and PCa is conflicting. However, the most research consistently shown that overweight/obesity was associated with higher risk of high-grade PCa and dying of PCa.

Overweight/obesity can promote high-grade PCa through increased levels of secreted adipokines, increased formation of proinflammatory agents, and reduced concentration of adiponectin, among others. Being obese may by also linked with a higher risk of mortality. Exercise can decrease these health consequences related with obesity and may be effective in reduction of PCa-specific mortality, however, there are relative few studies on PA and PCa prevention among obese individuals.

Key words overweight, obesity, prostate cancer, inflammation, physical activity

Introduction

Prostate cancer (PCa) is the second most frequently diagnosed malignancy in men worldwide (7.1% of the total cancer cases) and deaths (3.8% of the total dying from cancer) (Bray, Ferlay, Soerjomataram, Siegel, Torre, Jemal, 2018). Consistent with potential PCa risk factors, age, obesity, family history of the disease, smoking status, alcohol consumption, race, physical inactivity, and high energy intake are generally considered the most influential

risk factors (Giovannucci, Liu, Platz, Stampfer, Willett, 2007, Ferro et al., 2017). Obesity is a major risk for several diseases: Cardiovascular, musculoskeletal and some cancers, including PCa. Globally more than 1.9 billion (39%) adults were overweight in 2016, of these more than 650 million (13%) were obese (WHO, 2016). Literature search on the association between excess body weight and PCa generates mixed findings: Overweight and obese men may have a greater likelihood of developing more advanced PCa and dying from the disease than those within a normal weight range. Some studies also suggested that overweight/obesity may decrease the risk of in situ cancer or they are without effect on the PCa development (MacInnis, English, 2006; Renehan, Tyson, Egger, Heller, Zwahlen, 2008; Allott, Masko, Freedland, 2013). Thus, the collective evidence is not entirely consistent. Also, there are controversial associations between body weight excess and biochemical recurrence and PCa-specific mortality (Allott et al., 2013).

Interest in the role of physical activity (PA) in the primary prevention of obesity and normal body weight maintenance and cancer is increasing as the evidence for the beneficial effects of PA on metabolic rate, increased energy expenditure, body mass and fat reduction, and attenuation of morbidity and mortality risks rapidly accumulates (Kim et al., 2017). Evidence has showed that obesity may be linked with low PA level, however to what extent exercise can decrease the risk associated with overweight/obesity remains unclear (Kim et al., 2017). In view of these conflicting facts and limited knowledge of the efficacy of PA in body weight reduction among obese individuals, the main objective of this review article is to summarize what is currently known about the association between overweight/obesity and PCa development, progression, biochemical recurrence (BH), PCa-specific death and the role of PA in the body weight reduction and maintenance. We also identify gaps of the observational studies to give general overview of current state of knowledge in this area of research and discuss the proposed biological mechanisms linking overweight/obesity with PCa, risk, emphasizing the possible preventive role of PA.

Materials and methods

Search strategy

A literature search was carried out in PubMed, Scopus, Health Source, Scientific Direct, Web of Science, and MEDLINE for studies reporting obesity or overweight – mediated changes in the PCa risk, progression, and the disease specific death until March 2022. The following combination of search terms and key words was used: *prostate cancer/prostate carcinoma and overweight/obesity/body weight excess, physical activity/exercise*, *sedentary lifestyle and overweight/obesity/body weight excess and prostate cancer/prostate carcinoma*. Only English language papers were included in the analyses. The following criteria we used to assess relevance to the study problem: Original cohort and case-control studies which investigated the relationship between overweight/obesity and the risk of PCa development progression, or the risk of BH and cancer mortality among PCa survivors.

Inclusion criteria

This overview included papers reporting observational epidemiological studies, reviews, meta-analyses, case-control studies, and cohort studies dealing with the association between overweight/obesity PA and PCa. Articles as conference abstracts, commentaries, and editorials were excluded. Inclusion criteria included physical-diagnosed cancer confirmed by histopathological examination (biopsy or radical prostatectomy), PCa grades (e.g., in situ, locally advanced, advanced, fatal), and overweight/obesity measurement tools. Case-control studies

were included when odds ratio (OR) with 95% confidence interval (CI) or P value trends (determining statistical significance), numbers of cases and controls for each specific cancer grade and adjustment at least for age were reported. Cohort studies were included with relative risk (RR), hazard ratio (HR) estimates, and number of PCa cases and controls or those reporting incident cases and person-year. Both case-control and cohort studies had to include the representative numbers of cases and controls and were adjusted for the main PCa risk or contained the matched groups with respect to age, family history of PCa, and ethnicity groups.

Data extraction

Data on the type of study, study design, authors, publication journal and year, participant characteristic, grade of cancer, number of patients (cases) and controls, variables of adjustment and the study limitations, and effect size were extracted from articles. References were also searched to identify additional articles.

Results and discussion

Body weight excess in relation to prostate carcinoma

Overweight/obesity is a significant public health problem occurring in both developed and developing countries (De Pergola, Silvestris, 2013; Renehan, Zwahlen, Egger, 2015). Overweight and obesity are assessed using Body Mass Index (BMI – body weight/height, kg/m^2), waist circumference, and waist-hip ratio (WCRFI/AICR, 2014). Overweight is defined as a BMI of 25 kg/m^2 to 29.9 kg/m^2. Obesity is a stage in obesogenesis (a disorder arising from chronic deregulation of energy balance and characterized by the inordinate accumulation of fat) and is determined by BMI of 30 kg/m^2 or greater (WHO, 1997). Excess body weight results from several risk factors, including genetic predispositions, unhealthy dietary patterns, physical inactivity, metabolic, environmental, socioeconomic, and psychological factors (Dobbins, Decorby, Choi, 2013).

According to a World Health Organization (WHO) estimation, worldwide obesity has reached approximately threefold increase since 1975, and in 2016 more than 1.9 billion adults (including over 650 million obese people) were overweight (Smith, Smith, 2016; WHO, 2018). According to the World Population Review, 2020 statistic (Obesity rates by country 2020, 2020) the number of overweight people worldwide in 2019 was estimated at 2.1 billion, what is about 30% of the total population. Obesity caused three million deaths. It is expected that 58% of adults globally will be overweight or obese by year 2030 (Smith, Smith, 2016).

For PCa classification the Gleason grading system and its modification by The International Society of Urological Pathology have been used by pathologists and clinicians as predictors of BH (Humphery, 2004; Chen, Zhang, 2016). Briefly, the Gleason scores system realized scale, ranging from 1 to 5 degrees and a sum of Gleason scores, determining two dominating cancer cell types in a sample during biopsy, ranging theoretically from 2 to 10. However, Gleason score 1 + 1 = 2 should not be diagnosed and a Gleason score 3 (grades 1 + 2, 2 + 1) or score 4 (grades 2+2) has been reported as controversial (Chen, Zhan, 2016). Gleason score 5 (comprised of grades 2 + 3 = 5 or 3 + 2 = 5) would be diagnosed if the edge of a tumor exhibits slight irregularity (Chen, Zhan, 2016). Consequently, Gleason scores range from 6 to 10, and scores of 6 and 7 determine low and intermediate grades of cancers, respectively, whereas a scores of 8 to 10 determine a high-grade tumor (Humphery, 2004). In turn, the modified Gleason grading system (the Grade Groups) is based on five grades, 1 through 5: Grade Group 1 (Gleason score ≤6) – low/very low risk group, Grade Group 2 (Gleason score 7 (3 + 4) and Grade Group 3 (Gleason score

7 (4 + 3)) – intermediate risk group, Grade Group 4 (Gleason score 8 (4 + 4)) and Grade Group 5 (Gleason score 9–10) – high/very high-risk group (Egevad et al. 2016; Cancer Foundation, 2022).

Table 1 shows the characteristics of the representative epidemiological studies presenting the effect of overweight/obesity on PCa risk (n = 22) including first author name, year of publication, participants, cases, main results, and comments from each study (Bashir, Ahmad, Malik, 2014; Vidal et al., 2014; Bai et al., 2015; De Cobelli et al., 2015; Hu et al., 2015; Lee, Chia, 2015; Heir, Falk, Robsahm, Sandvik, Erikssen, Tretli, 2016; Khan et al., 2016; Möller et al., 2016; Dickerman et al., 2017; Kelly et al., 2017; Perez-Cornago et al., 2017; Vidal et al., 2017; Wu et al., 2017; Zhao et al., 2017; Lavalette et al., 2018; Yu, Byun, Lee, Hong, 2018; Zeigler-Johnson, Hudson, Glanz, Spangler, Morales, 2018; Kelly et al., 2019; Langlais et al., 2019; Hurwitz et al., 2020; Vidal et al., 2020). In most of the studies BMI has been applied as a measure of overweight/obesity.

Table 1. Epidemiological studies looking at the effect of excess body weight on prostate cancer

Study	Study design/sample size (follow-up time)	Sample size	Control for confounding	Main results and comments cancer risk (95% CI)
1	2	3	4	5
Bashir et al., 2014 Pakistan	Hospital-based case-control study (2012–2013)	140 cases, 280 controls	Yes	*Increased risk* of total PCa BMI >25 kg/m^2 *vs* ≤25 kg/m^2 OR: 5.79 (2.66–12.60)
Vidal et al., 2014 USA	Clinical study (REDUCE) (4 years)	1,739 normal weight 3,384 overweight 1,304 obese after at least one biopsy	Yes	*Decreased risk* of low-grade PCa by 21% in men with BMI ≥30 kg/m^2 *vs* <30 kg/m^2 and no cancer *Increased risk* of high-grade PCa by 28% in men with BMI ≥30 kg/m^2 *vs* <30 kg/m^2 and no cancer
Bai et al., 2015 China	Retrospective study (February 2006 – December 2014)	211 patients treated with prostatectomy	Yes	*Increased risk* Higher BMI positively correlated with higher biopsy Gleason score (≥7) and BH OR: 1.163 (1.023–1.322) OR: 1.22 (1.06–1.41), respectively
De Cobelli et al., 2015 Italy	Retrospective study (November 2008 – May 2014)	311 patients after radical prostatectomy	No	*Increased risk* Obese men were found at higher risk of upgraded (Gleason score ≥7) disease by 21% and upstaged (pathological stage >pT2) disease by 23%, for 1 unit increase in BMI
Hu et al., 2015 China	Retrospective study (December 2004 – February 2014)	1,651 men with initial multicore ≥10 of prostate biopsy, 750 cases (419 with high grade PCa)	Yes	*Increased risk* of overall PCa BMI ≥30.0 kg/m^2 *vs* <18.5–22.9 kg/m^2 OR: 1.17 (1.10–1.20) No association for high-grade PCa OR: 1.03 (0.97–1.09)
Lee and Chia, 2015 Singapore	Retrospective study (January 2012 – April 2014)	458 men (125 men with positive PCa on biopsy)	Yes	*Increased risk* of positive initial biopsy BMI = 25–29.9 kg/m^2 *vs* <25 kg/m^2 OR: 2.6 (1.58–4.30) BMI ≥30 kg/m^2 *vs* <25.0 kg/m^2 OR: 3.26 (1.37–7.73)
Heir et al., 2016 Norway	Cohort (aged 40-59y) in 1972-1975 followed through 2012	1,997 healthy men (213 cases, 62 cases in advanced cancer stage)	Yes	*Decreased risk* of overall PCa BMI ≥25 kg/m^2 *vs* <25.0 kg/m^2 SHR: 0.69 (0.52–0.93)

1	2	3	4	5
Khan et al., 2016 USA	Population-based cross-sectional case-control study	2,049 men diagnosed with PCa	Yes	*Increased risk* of advanced PSA (Gleason sum ≥8 or PCa >20 ng/mL or Gleason sum = 7 and clinical stage cT3-cT4) BMI ≥30.0 kg/m^2 *vs* 18.5–25.0 kg/m^2 White Americans: OR: 1.98 (1.14–3.43) *No significant association* found in the overall sample and in Black subjects
Möller et al., 2016 USA	Health Professionals Follow-up Study (1986-2010)	47,491 individuals, 6183 cases	Yes	*Decreased risk* BMI ≥30.0 kg/m^2 *vs* <21.0 kg/m^2 Age 21y Total PCa RR: 0.89 (0.80–0.98), advanced (T3b/T4 stage) PCa RR: 0.69 (0.53–0.89). Gleason score 7 RR: 0.77 (0.64–0.93). Age ≤65y Total PCa RR: 0.64 (0.51–0.78) Non-advanced PCa RR: 0.57 (0.41–0.74) *No association* for men aged >65y
Kelly et al., 2017 USA	Prospective cohort follow-up study (11.5 years)	69,873 men from 10 cancer screening centers (7,822 cases, 3,078 aggressive, 4,587 nonaggressive, and 255 fatal PCa)	Yes	*Increased risk* of mortality (fatal PCa) BMI estimated in the range 18.5–≥ 30 kg/m^2 HR: 1.27 (1.03–1.58) for an increment of 5 kg/m^2 of BMI BMI ≥30 kg/m^2: HR = 1.69 (0.75–3.82), P trend = 0.004 BMI ≥30 kg/m^2: Age 20 years HR = 1.69 (0.75–3.82), P trend = 0.004, Age of 50y HR = 1.55 (1.05–2.29), P trend = 0.05 Change in BMI between age 20 years and baseline (mean 63 years) increased significantly risk of mortality: HR = 1.95 (1.21–3.12) (normal to obese) HR = 2.65 (1.35–5.18) (overweight to obese cases) *No significant association with BMI for aggressive and nonaggressive PCA*

1	2	3	4	5
Dickerman et al., 2017 USA	Prospective cohort study (1986–2012)	51,529 men 5,158 with localized PCa (T1/T2), (371 lethal cases, 804 biochemical recurrence events)	Yes	*Increased risk* of lethal PCa with long-term weight gain among never smokers (N = 2,559) HR = 1.59 (1.01–2.50), P trend 0.06 for weight gain >30 pounds. The relationship between weight change and PCa was stronger among men with BMI ≥25 kg/m^2 at age 21 comparing with those with BMI <25 kg/m^2 Obesity and weight gain were not associated with BH
Perez-Cornago et al., 2017 France	Multicenter prospective cohort study (EPIC) (13.9 years of follow-up)	7,024 PCa cases (726 with high grade PCa, 1,384 with advanced stage) 2,622 with localized cancer 931 deaths from PCa	Yes	*Increased risk* of aggressive PCa BMI >27.0 kg/m^2, Gleason score of ≥8 HR = 1.32 (1.01–1.72) WC >103 cm HR = 1.43 (1.07–1.92) *Increased risk* of PCa deaths BMI >29.2 kg/m^2 HR = 1.35(1.09-1.69) Waist circumference >103 cm HR = 1.55 (1.23–1.96)
Zhao et al., 2017 China	Retrospective cohort study (December 2004 – February 2014)	3,102 patients (974 diagnosed as PCa cases, 700 treated with prostatectomy, 1,031 had biopsy negative (reference group). 217 normal weight (BMI <25 kg/m^2), 218 overweight (BMI = 25–<30 kg/m^2), 140 middle obese (BMI = 30–<35 kg/m^2), 125 severe obese (BMI ≥35 kg/m^2)	Undefined	*Increased risk* of aggressive PCa Overweight OR = 2.304 (1.469–3.615) Middle obese OR = 3.144 (1.869–5.290) Moderately and severe obese OR = 3.300 (1.852–5.880), *vs* normal weight Increased risk of BH after radical prostatectomy among obese men vs nonobese men HR = 1.405 (1.405–1.903) Increased risk of BH with low level of the high-density lipoprotein cholesterol
Vidal et al., 2017 USA	Retrospective study (followed from 1990)	4,268 men after radical prostatectomy (at least 6.8 years)	Yes	*Increased risk* of PCa specific mortality BMI 25.0–29.9 kg/m^2 *vs* <25 kg/m^2 HR: 1.88 (0.97–3.63) (insignificant) BMI ≥30.0 kg/m^2 *vs* <25.0 kg/m^2 HR: 2.05 (1.04–4.06)
Wu et al., 2017 USA	Retrospective study (January 2001 – March 2016)	1,788 men after radical prostatectomy (37.5% overweight, 32.9% obese)	Yes	*Increased risk* Obesity positively linked with advanced PCa but not with ethnicity

1	2	3	4	5
Lavalette et al., 2018	EPICAP population-based case-control study (2012–2013)	819 cases (183 with aggressive PCa) 879 controls	Yes	*Increased risk of aggressive PCa* WC, cm: 95–102 *vs* ≤94 OR: 2.20 (1.32–3.69) >102 *vs* ≤94 OR: 3.27 (1.70–6.30), Ptrend = 0.004 WHR: 0.95–0.99 vs <0.95 OR: 1.40 (0.87–2.23) ≥1.00 OR: 1.77 (1.08–2.87) Ptrend ≤0.02 Obesity is a risk for PCa particularly for aggressive cancer; WC is a better index of abdominal obesity than WHR A lack of association between BMI and PCa risk
Zeigler-Jonson et al., 2018 USA	Study of Clinical Outcomes Risk and Ethnicity (SCORE) (1998–2010)	1,576 radical prostatectomy patients categorized on three risk recurrence groups: low, medium, high (Kattan nomogram score <10 CaPSURE/cPDR score <7.2; 10–50; 7.1–16.7; 50–100; >16.7, respectively) based on PSA value, Gleason score and tumor stage (338 obese, 820 overweight, 373 normal weight men)	Yes	*Increased risk* of BH in medium and advanced PCa groups: Medium risk group HR = 2.99 (2.29–3.88) High risk group HR = 8.84 (5.91–13.20), *vs* low risk group A lack of statistically significant association between risk of BH groups across BMI groups
Yu et al., 2018 Korea	Retrospective cohort study (January 2006 – May 2017)	2,997 radical prostatectomy patients: 867 normal weight (BMI <23 kg/m^2), 1,799 overweight (BMI ≥23–<27.5 kg/m^2), 331 obese (BMI ≥27.5 kg/m^2)	Yes	*Obesity was significantly associated* with BH BMI ≥27.5 kg/m^2 was an independent predictor of BH-free- survival: HR = 1.268 (1.095–1.899) *vs* normal weight patients For PCa specific mortality: HR = 2.334 (1.501–3.080) Positive surgical margin rates, extra prostatic invasion, advanced Gleason score (≥8), and lymph node invasion were significantly greater among obese men compared to overweight and normal patients
Langlais et al., 2019 USA	Retrospective cohort study (1995–2018)	3,230 radical prostatectomy cases: 937 normal weight 1,998 overweight 719 obese 193 very obese	Yes	*Increased prognostic risk* at time of diagnosis for obese men OR = 1.5 (1.2–1.8), and very obese OR = 1.7 (1.12–2.30)

1	2	3	4	5
Kelly et al., 2019 USA	Prospective cohort study within National Institutes of Health-American Association of Retired Persons (1995–1996)	153,730 men 630 fatal PCa cases, 16,896 incident cases (2,185 aggressive)	Yes	*Increased risk* of fatal PCa for an increment of 5 kg/m^2 of BMI increase Mid-to-late BMI (mean age 63 year) HR = 1.12 (1.01–1.24) Adulthood maximum BMI (all ages) HR = 1.2 (1.02–1.24) Increased risk of fatal PCa for substantial weight gain during adulthood among never smokers (all ages) HR = 1.27 (1.02–1.49) Increased BMI from normal (18.5–24.9kg/m^2) to obese (≥30.0 kg/m^2) (n = 18 cases) HR = 2.37 (1.38–4.09) *vs* men who maintained a stable BMI
Hurwitz et al., 2020 USA	Case-control study	566 cases, 964 controls	Yes	*Increased risk* of PCa incidence BMI ≥30 kg/m^2 *vs* BMI <25 kg/m^2 OR = 1.86 (1.11–3.13) Elevated WC: OR = 1.76 (1.24–1.51) Elevated WHR OR = 1.46 (0.99–2.16) Overal and abdominal obesity positively linked with PCa risk regardless of cancer grade
Vidal et al., 2020 USA	Retrospective cohort follow-up study (7.4 years)	5,929 patients (1983 black men: 1321 normal weight, 2605 overweight, 2003 obese. Patients identified with BH 1891, with castration-resistant PCa 181, 259 men had metastasis, and 135% had died of PCa	Yes	*Increased risk of mortality* *Obesity was significantly linked with PCa* – specific mortality (p = 0.035): HR = 1.78 (1.04–3.04), regardless of race. A lack of association between overweight/obesity and BH, castration-resistant PCa, or metastasis

Note. PCa – prostate cancer; BMI – body mass index; HR – hazard ratio; CI – convenience interval; OR – odds ratio; BH – biochemical disease recurrence; WC – waist circumference; WHR – waist-hip-ratio.

The following associations between overweight/obesity and PCa were reported: significant increased risk of total cancer associated with excess body weight (17–579%) (Bashir et al., 2014; Hu et al., 2015;Lee, Chia, 2015; Langlais et al., 2019; Hurwitz et al., 2020), aggressive cancer progression (16–330%) (Vidal et al.; 2014, Bai et al.; 2015, De Cobelli et al.; 2015, Khan et al.; 2016, Perez-Cornago et al., 2017; Wu et al., 2017;Zhao et al., 2017; Lavalette et al., 2018), PCa-specific mortality (35–205%) (Dickerman et al., 2017; Kelly et al., 2017; Perez-Cornago et al., 2017; Vidal et al., 2017; Yu et al., 2018; Kelly et al., 2019; Vidal et al., 2020), and BH (22–884%) (Bai et al., 2015; Zhao et al., 2017;Yu et al., 2018; Zeigler-Johnson et al., 2018). Several researchers reported a decreased risk of low-grade overall PCa in overweight/obese individuals (21–53%) (Vidal et al., 2014; Heir et al., 2016; Möller et al., 2016) as well as the non-advanced and advanced cancer (Möller et al., 2016). A lack of association between excess of BMI and total PCa (Khan et al., 2016; Möller et al., 2016; Lavalette et al., 2018) or BH was also observed (Dickerman et al., 2017). The incidence ratios were adjusted mostly for the important confounding factors, such as age, race, education, and PCa screening history. Unfortunately, only two studies reviewed here were adjusted for PA (Möller et al., 2016; Perez-Cornago et al., 2017), six studies for cigarette smoking (Bashir et al., 2014; Möller et al., 2016; Kelly et al., 2017; Perez-Cornago et al., 2017; Langlais et al., 2019; Hurwitz et al., 2020), and one study for alcohol

intake (Bashir et al., 2014). Also, other possible confounding factors in the study of for the obesity/overweight and PCa association, like environmental factors (radiation, infection agents, occupational exposures) were not included in the analyses. We found evidence that increased BMI and/or BMI change during a life course that resulted in obesity were linked with greater risk of advanced and fatal prostate cancers. Observational evidence confirmed also a consistent and strong correlation between obesity and PCa-specific death. Although, few observational studies also reported a protective role of obesity for the risk of local PCa. These results agree with existing literature.

Evidence from previous reviews and meta-analyses clearly demonstrate a significant relationship between overweight/obesity and PCa development, progression, and cancer specific mortality, however, results are mixed (Cao, Ma, 2011; Discacciati, Orsini, Wolk, 2012; Chen et al., 2016; Zhong et al., 2016; Jiang, Chen, 2017). Most meta-analyses included large cohort studies with modest enhancing effect of BMI on the incidence of advanced and high risk PCa (men who have a high Gleason grade, elevated PSA and high tumor stage), subjects experienced a 2-33% higher risk for every 5-kg increase in BMI (Discacciati et al., 2012; Chen et al., 2016; Jiang, Chen, 2017; Vidal et al., 2017). A few of them (Cao, Ma, 2011; Chen et al., 2016; Zhong et al., 2016; Jiang, Chen, 2017) reported an increase from 12% to 20% in PCa specific mortality for every 5-kg increase in BMI, however one study (Zhong et al., 2016) reported only prediagnostic BMI but not post-diagnostic BMI that could be linked with increased risk of death from PCa. In turn, Discacciati et al. (2012) showed an inverse relationship between BMI and localized PCa, reporting a 6% decrease in cancer risk per 5 kg/m2 increase of BMI, and Vidal and Freedland (2017) presented decreased risk of low-grade cancer by 20% among Caucasians and increased risks in obese black men for both low- and high-grade PCa by 122% and 81%, respectively. The authors underlined the importance of cancer progression duration, e.g. a lack of cancer progression for 12 months, but strongly increased progression for longer observation time. Two meta-analysis studies (Bai et al., 2015; Cao, Ma, 2011) reported an approximate 20% higher risk of BH in overweight/obese individuals after primary PCa treatment, however, in one of them (Bai et al., 2015) the association between BMI and the cancer recurrence did not reach statistical significance. Also, review by Trivedi, Samson, Orekoya (2016) reported strong evidence that obesity is associated with both PCa aggressiveness and mortality. In turn, a review of three much earlier meta-analyses, published between 2001–2008 by Allott et al. (2013), indicated a positive relationship between obesity and aggressive PCa risk. The authors found statistically significant increases in the PCa risk by 1–5% per 1 kg/m^2 increase in BMI and a dichotomous effect of obesity on PCa incidence, i.e., including a protective effect of obesity against cancer assessed in some prospective cohort studies, similarly to what we observed in several recent studies presented in Table 1.

The magnitudes of positive association of advanced PCa risk and mortality found in our study were larger than the summary relative risks reported by the reviews' authors. However, these results must be viewed with caution due to significant heterogeneity across the rated studies. In addition, these conflicting outcomes may result from large geographical differences in incidence rates of PCa and obesity and in genetic susceptibility as well as from the use of different methodologies and individual follow-up times. In addition, observational studies often did not include a full list of potential confounders in statistical models, e.g. PA or nutrition, thus often suffered from high heterogeneity.

There are several hypothesized mechanisms where overweight and obesity may influence prostate carcinogenesis and metastasis due to adipose tissue, such as elevated levels of insulin in serum, insulin-like growth factor-1 (IGF-1) and triglycerides, insulin resistance, deregulation of steroid hormones concentrations, resulting in the increased estrogen to androgen ratio, and alteration of proinflammatory adipokines level, e.g. leptin

(as summarized in Figure 1) (Calle, Kaaks, 2004; Roberts, Dive, Renehan, 2010; Rowlands et al., 2012; Williams, 2012; Hopkins, Goncalves, Cantley, 2016; Santoni et al., 2019).

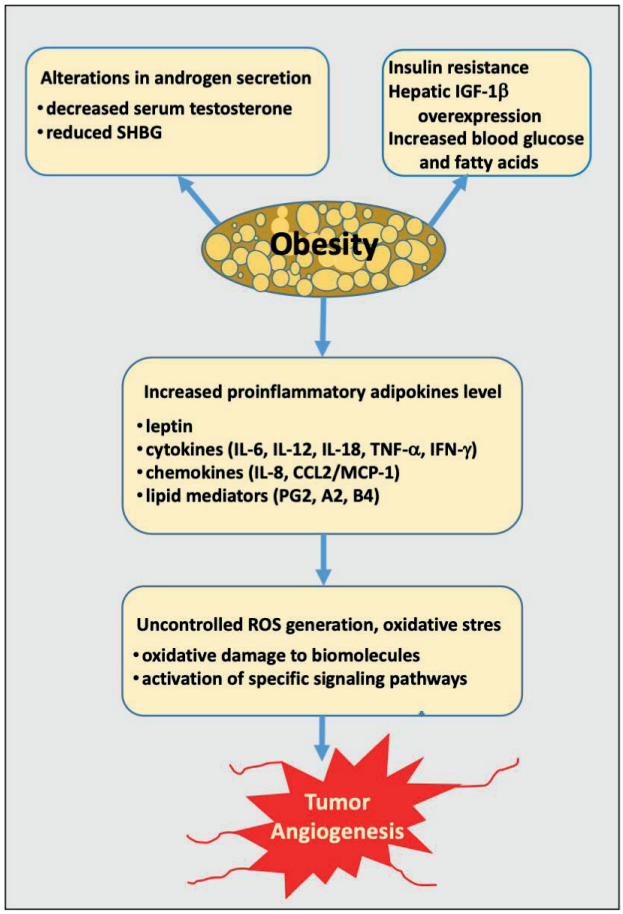

Figure 1. Schematic overview of potential effects of overweight/obesity on prostate carcinogenesis

Evidence shows that excess adipose tissue acting as an endocrine organ involves metabolic dysregulation and secretes adipokines. Obese individuals have increased levels of tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), leptin, insulin and IGF-1, and decreased level of adiponectin (Santoni et al., 2019). Insulin resistance often accompanying obesity and high concentration of IGF-1 can activate and up-regulate IGF-1 and insulin receptors and activate several intercellular signaling pathways, e.g. P13K/AKT (phosphoinositide 3-kinase/protein kinase B), HIF-1α (hypoxia-inducible factor-1 alpha), VEGF (vascular endothelial growth factor), mTOR (mechanistic target of rapamycin), promoting the survival and proliferation of tumor cells (Santoni et al., 2019). Also, a higher blood glucose concentration is a source of energy for cancer cell growth and proliferation (Champ, Francis, Klement,

Dickerman, Smith, 2016). In addition, increased levels of blood fatty acids in obese individuals and their catabolism via β-oxidation support cancer growth and survival (Koundouros, Poulogiannis, 2020). Further, high levels of leptin in obese individuals can lead to the leptin/leptin receptor ratio dysregulation, and via JAK2/STAT (janus kinase-2/signal transducer and activator of transcription), P13K/AKT, and MAPK (mitogen-activated protein kinase) signaling pathways to the development of cancer (Dutta, Ghosh, Pandit, Mukhopadhyay, Chowdhury, 2012). In addition, leptin may directly induce the generation of the ROS intermediates in macrophages, neutrophils and endothelial cells as well as enhances expression of NO synthase, among others, and contributes to chronic inflammation in obesity (Mancuso, 2016). Epidemiological evidence maintained extremely high leptin concentrations in serum of patients with several types of cancer, including PCa.

Several recent studies concluded that adiponectin may be a very important hormone in mediation of the association between obesity and PCa (Fang, Judd, 2018). This protein hormone modulates several metabolic processes, among them glucose level and fatty acids oxidation. Adiponectin also increases activity of peroxisome proliferator – activated receptor alpha (PPARα) ligand (Fang, Judd, 2018) and inhibits VEGF A activity in PCa cells (Gao, Zheng, Yao, Peng, 2015). Unfortunately, adiponectin levels in obese individuals are low.

The latest evidence on the role of obesity in aggressive cancer development suggests that infiltration of periprostatic adipose tissue by tumor cells and secretion of proinflammatory cytokines, e.g. interleukin-1 (IL-1), interleukin-6 (IL-6), and TNF-α, are key steps in cancer progression (Fujita, Hayashi, Matsushita, Uemura, Nonomura, 2019; Santoni et al., 2019). In addition, increased levels of reactive oxygen and nitrogen species (ROS, RNS, respectively), released at inflammation sites due to deregulation of homeostasis, can drive carcinogenesis (Klaunig, Kamendulis, Hocevar, 2010; Kruk, Aboul-Enein, 2017; Aggarwal et al., 2019). A dual role of inflammation is known. The first role is protective, when the process is directed against an infection with foreign organisms, injury or the therapeutic application. The second role – harmful, when the process leads to chronic inflammation being the precursor of inflammatory diseases, including cancer. The long-term inflammation along with oxidative stress (OS) and nitrosative stress (NS) is a key factor in cancer onset and progression by forming tumor microenvironment (Aggarwal et al., 2019). Evidence shows an interconnection between OS and inflammation. Under pathological conditions due to excess of ROS/RNS production, inflammation can enhance OS, e.g. through enhancing COX-2 activity and ROS/RNS are formed in excess, increasing cell damage. Metabolic changes linked with long-term weight gain can lead to the disturbance of cellular homeostasis towards ROS/RNS overproduction and contribution to abnormal gene expression and mutations. The excessive production of ROS plays a crucial role in the stimulation of signaling pathways and angiogenic factors, oncogenes activation, apoptosis inhibition, necrosis induction, and tumor suppressors inactivation (Klaunig et al., 2010, Aggarwal et al., 2019). Indeed, an increased concentration of ROS has been detected in several cancers, including PCa. These oxygen species can stimulate carcinogenesis by participation in all its stages (Klaunig, Kamendulis, Hocevar, 2010).

The collective evidence we reviewed agrees with the judgment of the WCRF/AICR Continuous Update Project (2014). Based on the global scientific research of 9,858,000 men including 191,000 PCa cases, Expert Panel concluded that “greater body fatness (marked by BMI, waist circumference, and waist-hip ratio) is *probably* a cause of advanced PCa” (p. 36).

Effect of physical activity/exercise on body weight and body fat

Energy expenditure is the sum of the amount of energy used for basal metabolism (the basal and resting metabolic rate, BMR) to maintain vital activity of cells, respiration, and circulation, energy expenditure from spontaneous PA, activity linked with daily living, and dietary thermogenesis (the energy needed to digest, absorb, and store food). The BMR component of total energy expenditure makes up 60–70%, the component linked with PA comprises 20–30% and diet induced thermogenesis – approximately 10% (Lakka, Bouchard, 2007). Energy expenditure during PA is the most variable component of the total energy expenditure ranging from 400 to 3,000 kcal/day between individuals. Total daily energy expenditure is affected by endogenous and exogenous factors, e.g., genetics, age, metabolism, BMI, and diet or endocrine responses to a stressful agent (Melzer, 2011). The complete characteristic of PA includes domains of activity (e.g., resistance exercise, aerobic exercise), frequency, duration, and intensity. During resistance exercise the body uses glycogens as a fuel and strength of muscles, e.g. exercising with weight machines or lifting heavy load. In turn, in aerobic exercise larger groups of muscle are engaged, and the energy originates from burning of glycogens and fat stores, running, swimming and brisk walking are examples. Intensity of PA/exercise is commonly expressed using metabolic equivalents (METs) estimating the energy cost of individuals. The following intensity levels are specified: Sedentary behavior <1.6 METs, light-intensity, 1.6–2.9 METs, moderate-intensity, 3.0–5.9 METs, vigorous-intensity, ≥6 METs (WHO, 2020). One MET corresponds to a standard resting metabolic rate of 1.0 kcal · kg^{-1} · h^{-1} (the energy expenditure corresponds to individuals at rest). The MET values determine the ratio of the activity-related metabolic rate to a standard resting metabolic rate.

Previous and current epidemiological studies have provided strong evidence for PA/exercise-induced weight and body fat reductions (Thorogood et al., 2011; Kim et al., 2017; Holliday et al., 2018). For example, findings from 14 trials (1,847 obese individuals) involved in a 6-month moderate exercise intervention experienced a weight reduction of 1.6 kg (95% CI: 1.56–1.64) and higher reduction (1.7 kg (95% 1.11–2.29)) and a decrease in WC (1.95 cm (95% CI: 1.29–3.62)) during 12-month intervention (Thorogood et al., 2011). Further, Holliday and co-workers observed that 150 min moderate intensity exercise/week resulted in significant reduced body weight (–3.3 ±5.9 kg) and WC (–2.8 ±4 cm) compared with controls (2.1 ±6.6 cm) in inactive overweight/obese women during a 24-week intervention (Holliday et al., 2018).

There is now clear evidence providing a combination of diet caloric restriction and regular PA as the most effective action to achieve a negative energy balance (Petridou, Siopi, Mougios, 2019). An interesting meta-analysis by Kim et al. (2017) examined the effect of aerobic PE of moderate and high intensity and resistance training with and without caloric restriction on body weight loss. The authors found stronger significant body weight reduction induced by exercise of high intensity (>5%) compared to that of moderate intensity (2–3%). When an exercise intervention was combined with caloric restrictions, body mass reductions were above 5% and 3–5%, respectively, and were stronger than those caused by diet reduction only. Study participants also experienced reduction in WC. Resistance training without caloric restrictions produced no change in body weight. Researchers noted the combination of caloric restriction and increased energy consumption through PA, e.g. brisk walking, climbing stairs will let obese individuals maintain weight for long periods after initial weight loss, thus they recommend 200–300 min/week of moderate intensity PA. The authors noticed that aerobic exercise may be a mean for body weight and fat mass reductions, while the beneficial effect of resistance training on weight loss was not confirmed. Also, a review by Mohamad et al. (2015) of randomized controlled trials (n = 20) carried out up August 2013 reported

the exercise intervention in combination with diet was effective in weight loss (mean body weight decreases were between 0.8 kg and 6.1 kg), the exercise intervention alone did not lead to weight loss.

So far, there are limited findings regarding compensatory changes, i.e. increased energy intake and/or non-exercise activity thermogenesis, accompanying aerobic exercise of high intensity. Evidence shows that a moderate dose of exercise might cause increase non-exercised activity thermogenesis without increased energy intake, while a dose of vigorous exercise could result in increased energy intake and an elevation of level of energy balance (Rosenkilde, Auerbach, Reichkendler, Ploug, Stallknecht, Sjödin, 2012). For this reason, observed losses in body mass and fat mass were not in proportion to the energy expenditure.

Summarizing, the current evidence has generally shown that regular PE of moderate intensity along with diet plays a key role in controlling body weight and preventing obesity. Independently on a magnitude of body weight loss or even its lack, each form of exercise is beneficial for obese individuals, considering exercise ability to fight the chronic low-grade inflammation and prevent against OS which accompany obesity.

Effect of physical activity on prostate cancer in overweight/obese men

The evidence for an association between PA/exercise and PCa incidence shows changing effect (Liu et al., 2000; Littman, Kristal, White, 2006; Lynch, 2010; Liu et al., 2011; Grotta et al., 2015; Benke, Leitzmann, Behrens, Schmid, 2018; McTiernan et al., 2018; Berger et al., 2019; Deb, Emmanuel, Emara, 2019) and is classified as limited suggestive (WCRF/AICR, 2018, McTiernan et al., 2019). Physical activity has not been consistently associated with PCa incidence, some studies have suggested an association between higher PA and decreased risk of PCa incidence, whereas other studies did not find such association. For example, Deb et al. (2019) reviewed studies from 1980 to 2018 on the relationship between PA and PCa incidence risk. The authors found increased risk or no effect of occupational PA in 10 studies, positive trend decreasing cancer risk with increasing level of PA in 4 studies, and a statistically significant decreased risk in the more active men (based on 10 studies). Evidence from this study has suggested that leisure-time PA was inversely associated with the risk of PCa cancer or showed adverse trend or no clear effect (17 studies), exhibited positive trend (9 studies) and a significant decrease of the risk with higher PA (6 studies). Twenty seven of these 56 studies were adjusted for BMI. The question of whether BMI influences the association between PA and PCa risk has rarely been demonstrated (Friedenreich, Stone, Cheung, Hayes, 2020). The previous studies by Giovannucci et al. (2005) and Patel et al. (2005) reported lower risks of more advanced PCa or high stage disease with increased recreational activity, the associations were independent on BMI. Further, a prospective study by Liu et al. (2000) (6,048 men) found no overall effect of PA on PCa risk in the total group as well as among men with BMI >25 kg/m^2. Findings of a prospective cohort study (34,757 participants, 583 incident cases) by Littman et al. (2006) found that greater activity (≥10.5 MET-hours/week) was associated with a non-significantly elevated risk of PCa incidence (HR = 1.5, 95% CI: 0.94–1.52) in the total group, while men who were normal weight had a decreased risk to marginal significance (HR = 0.69, 95% CI: 0.46–1.00) for this dose activity *versus* no activity. However, the authors noted a 37% decrease in risk in inactive obese men compared to inactive normal weight men. Another observational study of Zeeger et al. (2015) evaluated the association between PA and PCa risk with specific emphasis on interaction with BMI (58,279 participants, 1386 incident cases, follow up period 9.3 years. They observed an increased risk PCa for obese men (BMI >30 kg/m^2) who reported >1 hour/day PA and those with a high baseline energy intake. In turn, Grotta et al. (2015) analyzed data from 13,109 men (904 cases, follow-up period 13 years) on self-reported recreational and occupational PA and localized or advanced PCa,

focusing on modulating effect of BMI. The authors noted that high levels of occupational activity were associated with a nonsignificant decreased risk of overall localized, and advanced PCa. A significant interaction between BMI and leisure time activity was noted.

A meta-analysis by Liu et al. (2011) of 19 cohort and 24 case-control studies (88,294 incident cases) on the association between PA and incidence of the risk for PCa showed the decreased risks of PCa incidence associated with total PA (RR = 0.90, 95%CI: 0.84–0.95), occupational activity (RR = 0.81, 95% CI: 0.73–0.91) and recreational activity (RR = 0.95, 95% CI: 0.89–1.00) in men aged <65 years, comparing the highest level versus lowest level of activity. Stratified analyses on BMI attenuated nonsignificantly the risk reductions. The results showed that BMI is not an important confounder of the association PA with PCa. For example, PA was nonsignificant associated with a reduced risk of PCa (RR = 0.98, CI: 0.81–1.20) in individuals with BMI <25 kg/m^2 as well as in the group with BMI >25kg/m^2 (RR = 0.95, CI: 0.82–1.11).

The recent systematic review and meta-analysis conducted in January 2019 of 12 prospective studies (30,810 incident cases) published by Berger et al. (2019) found a statistically significant increased risk of PCa incidence (RR = 1.80, 95% CI: 1.01–1.39) for sedentary lifestyle in analyses not adjusted for BMI. The association was attenuated to null (RR = 1.02, 95% CI: 0.94–1.11) after BMI adjustment. Moreover, the authors noticed a 21% significantly increased risk of aggressive PCa in analysis that was not adjusted for BMI, and the association equal to null after an adjustment for BMI. Another meta-analysis of observational studies (48 cohort studies and 24 case-control studies, 151,748 incident cases) by Benke et al. (2018) found non-significant risk reductions for advanced and non-advanced PCa incidence by 8 and 5%, respectively. They observed a significant inverse association between long-term occupational activity (reduction of total PCa by 17%) based on 13 studies. Evaluation of the association by cancer subtype showed a 49% risk reduction for occupational activity and a 25% reduction of advanced/aggressive PCa risk with increasing recreational activity. The authors observed no statistically significant heterogeneity of the PA-PCa relationship according to BMI.

However, there is growing evidence suggesting that PA has shown to be more effective in reduction of PCa-specific mortality and probability of a relapse of this cancer site (Kenfield, Stampfer, Giovannucci, Chan, 2011; Richman et al., 2011; Baumann, Zopf, Bloch, 2012; McTiernan et al., 2018; Newton et al., 2018; Friedenreich et al., 2020; Kenfield et al., 2021). Kenfield et al. (2011) demonstrated a 61% reduction of PCa-specific mortality, while Richman et al. (2011) found a 57% reduction in cancer progression among individuals with higher PA levels (≥3 hours/week) compared with those with lower activity. In turn, McTiernan et al. (2019) reported a 38% significant reduction in the risk for PCa-specific mortality in individuals with the highest levels of PA compared with those with the lowest levels of total (recreational, non-sedentary occupational and leisure-time activities). Friedenreich et al. (2020) reviewed 136 articles through November 1, 2018, focusing on the association between prediagnosis and postdiagnosis PA and survival for all cancer sites. Evidence showed that higher postdiagnosis levels of total, recreational, occupational and transportation activities significantly decreased cancer specific mortality, HRs: 0.47, 95% CI: 0.31–0.71, 0.69, 95% CI: 0.56–0.85, 0.64, 95% CI: 0.47–0.91, 0.64, 95% CI: 0.43–0.93, respectively. The researchers also demonstrated a subgroup meta-analysis of the relationship between PA before cancer diagnosis and postdiagnosis and cancer-specific mortality separately by BMI ≥25 kg/m^2 *vs* <25 kg/m^2. The analysis did not show that benefit due to postdiagnosis activity was greater for PCa cases with BMI <25 kg/m^2 compared with those with BMI ≥25 kg/m^2.

In summary, the literature does not provide sufficient evidence on the preventive role of PA against all types of PCa (Kruk, Aboul-Enein, 2016; WCRFI, 2016; Benke, Leitzmann, Behrens, Schmid, 2018). However, data have emerged showing that individuals more engaged in PE may have a lower risk of developing of some subtypes of PCa and the risk of aggressive PCa. Moreover, PE delays the disease progression and PCa-specific mortality (Campos et al., 2018; Newton et al., 2018). Evidence has suggested several biological pathways of PA cope with PCa, although the detailed mechanisms require further research due to the complex nature of PE interaction on individuals and complexity of the carcinogenesis process, independly on BMI (Litman et al., 2006; Lynch, 2010; Wekesa, Harrison, Watson, 2016). An important mechanism involves production, secretion, and expression of myokines by the skeletal muscles or other cytokines in response to exercise (Lee, Jun, 2019; Severinsen, Pedersen, 2020). Other mechanisms for the exercise-PCa interaction involve indirect protective effects, such as: Reduction of overweight/obesity and adiposity, change of metabolic and sex hormones levels (estradiol, testosterone), decrease of IGF-1, increase of SHBG and insulin growth factor-binding protein-3 (IGFBP-3), reduction of proinflammatory factors and OS, increase of natural killer cells and T lymphocytes, improvement of the immune system function, enhancement of DNA repair mechanisms, amplification of the antioxidant enzyme system efficiency, increasing the level of one of the most important tumor suppressor genes (p53), decrease of the IGF-1/IGFBP-1 ratio, and activation of protein kinases, among others (Wekesa et al., 2015; Hojman, Gehl, Christensen, Pedersen, 2018). Importantly, PA may also decrease mortality risk of cancer patients with advanced PCa through a change of the tumor microenvironment for the less favorable conditions for tumor progression, influencing e.g., microvascular oxygenation hypoxia and vascular action (Wekesa et al., 2015).

Regarding overweight/obesity, alternations in levels of endogenous hormones have been suggested as the most acceptable mechanism through obesity may affect tumorigenesis and cancer progression (Litmann et al., 2006). Moreover, there is common consensus and clarity on the complex association between steroid hormones level and cancer disease. Evidence has shown that exercise increases SHBG and lowers testosterone levels, while obesity increases levels of estrogens and decreases concentrations of SHBG. In addition, it is important to note that acute bouts of long-lasting and high-intensity endurance exercises generate an excess of ROS/RNS and create OS, thus, exhibit the proinflammatory action. In this case, the interactions and synergy between obesity and PA in proinflammatory actions are probable. Evidence on the positive and negative effects of PA in humans was widely discussed in our previous article (Kruk et al., 2020). More research with good evaluation of PA all domains intensity, frequency, duration, BMI and PCa types is needed to explain whether the effect of PA on PCa risk varies between lean and overweight/obese individuals.

Conclusions

Overweight/obesity and a lack of sufficient PA are recognized risk factors for most chronic diseases, including cancer. Findings of recently published observational studies, being the subject of this overview, confirm the previous data that overweight/obesity may be important risk factor for prostate carcinoma and increased PCa-specific death rate. Current evidence suggests greater baseline BMI is linked with developing a greater risk of high-grade PCa recurrence and with risk of PCa-specific mortality. We observed magnitudes of risk reduction larger than the averages previously reported in the subject literature. However, several discrepancies occurred in this area which include different study groups, study design, limited number of prospective studies, small sample sizes, and often the statistical models were not matched for confounding factors, such as PA, diet, smoking, or alcohol intake which

may interfere with the PA-overweight/obesity association. We also observed a lack of randomized controlled trials in this field of study. We noticed multiple and interrelated mechanisms can cooperatively participate in the association of excess weight and PCa risk, among them are higher estrogen to androgen ratio and chronic psychological stress with consequent increased generation of proinflammatory agents and alteration in the cellular redox homeostasis. Obese individuals are characterized by increased levels of secreted adipokines, such as TNF-α, IL-6, IGF-1, leptin and insulin, blood fatty acids, and the reduced level of adiponectin that activate various signaling cellular pathways and support cancer cell growth, proliferation, and metastasis of tumors. Current evidence suggests that excess body weight in men after radical treatment for localized PCa may increase the risk of the disease BH. Moreover, findings generated an important hypothesis: Monitoring BMI change during the adult life course may help identify men at higher risk of developing fatal stage of PCa. Limited number of studies have carried out a separate risk estimates for the BMI category, evaluating the effect of PA on PCa risk, this requires future studies. There is a suggestion that overweight/obesity may attenuate benefits from PA in cancer survivors. This study highlights the importance of PA/exercise in intentional weight loss among men with PCa and prevention of weight regain. These lifestyle components are means of weight and fat loss, though the potency of their effects in obese individuals remains unknown. Growing evidence maintains that regular exercise of moderate intensity can affect PCa progression by reducing insulin resistance, decreasing IGF-1 and IL-6 levels, increasing adiponectin levels, and enhancing cellular antioxidant homeostasis. Future studies with control groups and longer time of follow-up should examine the underlying biological mechanisms involved in the pathways between overweight/obesity and PCa risk and progression and explore better intervention of PA dose that is required to reduce obesity among advanced disease patients.

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