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ORIGINAL ARTICLE

DIFFERENCES IN PRE-SEASON BIOMECHANICAL AND FUNCTIONAL OUTCOMES BETWEEN INJURED AND NON-INJURED FEMALE SOCCER PLAYERS

RÓŻNICE W WYNIKACH PRZEDSEZONOWEJ OCENY BIOMECHANICZNEJ I FUNKCJONALNEJ POMIĘDZY GRUPAMI KONTUZJOWANYCH I NIEKONTUZJOWANYCH PIŁKAREK NOŻNYCH

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ABSTRACT

Aim

To verify whether there is a difference in the value of pre-season biomechanical and functional tests scored by injured and uninjured players.

Material and methods

46 female players of a football academy took part in the pre-season biomechanical and functional evaluation including isokinetic tests, functional tests, fundamental movement screen tests, and postural stability tests (Biodex, FMS, Optojump, Delos), and then completed an online questionnaire reporting their injuries in the last round of the season.

Results

Out of 46 participants, 18 participants (19 injuries) suffered injuries in the area of the lower limbs. There was a difference between the groups (non-injured vs. injured) in the results of anthropometric measurements: age (13.0 vs. 25.0, p = 0.001), height (159 cm vs. 167 cm, p = 0.018), weight (48.5 kg vs. 60 kg, p < .001), as well as in the results of BMI (18.9 vs 21.5, p < .001), 3SLHT test for the left leg (2.6 vs 2.8, p = 0.044) and the right leg (2.5 vs 2.95, p = 0.001), FMS (20 vs 18, p = 0.026), flexion power / kg (0.8 vs 0.9, p = 0.039) and for the maximum time without contact test on the DELOS platform for the left leg (12.6 vs 16.6, p = 0.022).

Conclusions

There is a difference in the selected biomechanical and functional outcomes between the group of injured and uninjured players. The footballers who scored higher values in jump tests and FMS reported injuries that had occurred more often during the football season. Additionally, the injured players were older, higher, weightier, and had higher BMI when compared to the non-injured players.

Keywords: women's football, functional tests, isokinetic tests

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STRESZCZENIE

Cel

Weryfikacja, czy istnieje różnica w przedsezonowych wartościach testów biomechanicznych i funkcjonalnych wykonywanych przez kontuzjowane i niekontuzjowane piłkarki nożne.

Materiały i metody

46 zawodniczek akademii piłkarskiej wzięło udział w przedsezonowej ocenie biomechanicznej i funkcjonalnej obejmującej testy izokinetyczne, testy funkcjonalne, ocenę podstawowych wzorców ruchowych i testy stabilności posturalnej (Biodex, FMS, Optojump, Delos), a następnie wypełniło kwestionariusz online, zgłaszając swoje urazy w ostatniej rundzie sezonu.

Wyniki

Spośród 46 uczestniczek, urazu w obrębie kończyn dolnych doznało 18 zawodniczek (19 urazów). Odnotowano różnicę pomiędzy grupami (niekontuzjowane vs kontuzjowane) w wynikach pomiarów antropometrycznych: wiek (13.0 vs 25.0, $p = 0.001$), wzrost (159 cm vs 167 cm, $p = 0.018$), waga (48.5 kg vs 60 kg, $p < .001$), a także w wynikach BMI (18.9 vs 21.5, $p < .001$), testu 3SLHT dla nogi lewej (2.6 vs 2.8, $p = 0.044$) oraz prawej (2.5 vs 2.95, $p = 0.001$), FMS (20 vs 18, $p = 0.026$), mocy zgięcia/kg (0.8 vs 0.9, $p = 0.039$) oraz dla próby maksymalnego czasu bez kontaktu na platformie DELOS dla nogi lewej (12.6 vs 16.6, $p = 0.022$).

Wnioski

Istnieje różnica w wybranych parametrach testów biomechanicznych i funkcjonalnych pomiędzy kontuzjowanymi i niekontuzjowanymi zawodniczkami. Piłkarki, które uzyskały wyższe wartości w testach skoku jednonóż i testach FMS częściej zgłaszały uszkodzenia w trakcie sezonu piłkarskiego. Dodatkowo kontuzjowane zawodniczki były starsze, wyższe, cięższe i miały wyższe BMI w porównaniu z zawodniczkami niekontuzjowanymi.

Słowa kluczowe: piłka nożna kobiet, testy funkcjonalne, testy izokinetyczne

Introduction

Football is a dynamic sport that requires high neuromuscular control (precise passing, shots) (Jadczak *et al.* 2019), as well as physical fitness: quick acceleration, jumping, sudden change of direction, trunk stabilization and dynamic lower limb strength (Śliwowski *et al.* 2018). A discipline that requires so many different skills creates a high number of factors conducive to injury (Junge & Dvorak, 2004). Although it is a contact sport, most injuries occur without the involvement of an opponent (90% of muscle injuries and 51%–64% of joint / ligament injuries (e.g., ACL) (Lemes *et al.* 2021), which are defined as tissue overloads occurring where the force applied exceeds the absorption capacity (Ishøi *et al.* 2020). Adding to previous injuries, type of surface, experience (van Mechelen *et al.* 1992) and individual physical fitness, we get a multifactorial event (Colby *et al.* 2017), where only the last component seems to be modifiable. Certainly, the absence of injuries and, thus, the availability of players during the season is one of the elements of success in team sports. Absence may result not only in unfavourable results but also economic consequences and long-term health or psychological problems (Larruskain *et al.* 2018, Ekstrand *et al.* 2020, Lemes *et al.* 2021).

Statistically, female soccer players sustain an injury every 3.42/1000 hours of athletic competition (Crossley *et al.* 2020), and the overall epidemiology of soccer injuries states that lower extremity injuries are the most common in the sport, with up to 66% occurring noncontact (Lemes *et al.* 2021). Muscle injuries account for about 31%, and consequently, 37% of athletes do not participate in training or matches for this reason. Muscle injuries (about 92%) mainly affect the hamstrings (37%), adductors (23%), quadriceps/straight thigh muscle (19%) and calf muscles (13%). (Ishøi *et al.* 2020). Additionally, a 16-year analysis of UEFA professional (male) leagues showed that the 31 most commonly diagnosed injuries accounted for up to 78% of all incidents – a significant proportion was mild (absence of 7 days or less, 42% of those examined) or moderate (absence of 7–28 days, 56% of cases), and only 2% of cases were severe (absence > 28 days). The mild and moderate injury group was dominated by pain syndromes resulting from overload (muscle pain, inflammation, etc.) (Ekstrand J. *et al.* 2020).

Identifying potential risk factors from screening and introducing appropriate prevention during preparation can be key to reducing injuries. The use of prevention programs in different groups of athletes has been widely reported in the literature (Lemes *et al.* 2021), but there is far less work describing the characteristics of the injured athlete. It is confirmed that poor performance in proprioception tests is significantly associated with low back pain and an increased frequency of knee sprain injuries, as well as non-contact ankle sprains (Riva *et al.* 2016). Additionally, it was noticed that the ability to generate less low limb power may lead to more frequent sprains of the knee joint, where, at the same time, higher power was associated with a lower percentage of ankle sprains. (Henry *et al.* 2016, Iguchi *et al.* 2016). Previous studies also informed about the relationship between jump height and the risk of hamstring's muscles injury (Iguchi *et al.* 2016), and studies are discussing the association among injury occurrence and fundamental movement skills (Chorba *et al.* 2010) or isokinetic strength, with its limited usefulness in prediction of injury (Steffen *et al.* 2016, Bakken *et al.* 2018, Namazi *et al.* 2019). However, there are only few studies using the results of the generated power during flexion/extension movement per kilogram of body weight, which can provide an objective point of reference. Therefore, it is necessary to capture them to determine the contribution of various factors influencing the predisposition to injury, which requires an adequate number of screening tests (Larruskain *et al.* 2018). Thus, this study used the results of 4 tests and anthropometric data.

Most of the articles referring to a similar topic include only single tests (FMS/Biodex/push-up 1RM/LESS test) in their evaluation. There is also little information on the use of a preseason battery of several tests, especially in a group of female soccer players. Due to the constantly growing interest in the topic of prevention (Croisier *et al.* 2008), as well as factors predisposing a player to injury, and the small number of articles on similar topics, the authors aimed to compare the results of the preseason biomechanical and functional evaluation between groups of injured and non-injured female players.

Material and methods

Forty-six female football players, members of one football club, were included in the study. All of them participated in a complex pre-season evaluation using biomechanical tests based on the Biodex isokinetic test, FMS assessment, postural stability analysis on the DELOS system, and lower extremity power measurement with the Optojump test. The tests were performed as a standard pre-season protocol. During the football season, the players participated in training sessions and league matches according to the players' sports level. After finishing the football season, the players fulfilled an online questionnaire. The data regarding sustained injuries were collected respectively, and all problems that occurred within the football season were recorded.

An injury was defined as a musculoskeletal injury that occurred during training or a match, causing the need to report the incident to the coach. The injury caused discomfort during training/match, the need to consult a physician/physiotherapist, and prevented the athlete from participating in subsequent training or matches (Ekstrand *et al.* 2021).

All players were informed about the aim of the study and that the participation was voluntary and anonymous, and that all collected data will be treated confidentially. No formal approval was required since according to Polish law, the retrospective study did not require approval from the Bioethics Committee.

Isokinetic evaluation

A Biodex System 3 Pro isokinetic dynamometer (Biodex Corp, 49 Natcon Drive, P. O. Drawer S, Shirley, NY) was used to measure knee joint flexor and extensor strength. Prior to testing, the athlete performed a warm-up on a stationary bike lasting 10 to 15 minutes at moderate intensity. Dynamometer axis of rotation and subject position were set according to guidelines described in the literature (Jenkins *et al.* 2013). Three repetitions of the knee extension-flexion test were performed at the 60˚/s angular velocity. The subject performed concentric movements from 90˚ of flexion to full extension to measure knee joint extensor muscle strength and 3 concentric joint flexion movements from full extension to 90˚ of flexion. Then, the same protocol was used for the other limb. During the test, the athletes were verbally motivated to perform the movement at the highest possible intensity. The following data were collected: muscle torque [N – m], muscle torque/body weight [%], maximal power [Watts], and the agonist/antagonist ratio [%].

Postural stability tests

The DELOS platform and an electronic proprioceptive posture station (DPPS; Delos, Turin, Italy) were used to assess postural balance. The stand was connected to a computer with special software (Postural System Manager – PSM) and included an electronic rocker board (Delos Equilibrium Board – DEB), a posture reader with an infrared sensor (Delos vertical Controller – DVC), and a Delos Postural Assistant (DPA)-assisted support bar. The DVC, located on the sternum, measured trunk inclination in the frontal (x) and sagittal (y) planes using a 2-dimensional accelerometer unit. The DEB has one degree of instability in the frontal plane with automatic tilt measurement (Riva *et al.* 2016).

First, a static test was performed with the eyes open and on a stable surface (without the use of DEB) assessing the time without contact with the DPA for both limbs and leaning from vertical. A single trial lasted 20 seconds. The same procedure was then repeated with eyes closed. The athlete stood barefoot, alternating between the left and right leg with a 15-second interval between each trial. As a third, a dynamic postural priority test (DPPT) was performed on the DEB platform for both limbs. The software summed the test time without contact with the DPA and with the help of the bar. The subject looked at the monitor during the measurement in an attempt to minimize the amplitude of deflection from vertical. In each trial, the PSM analysed the pivoting in the x-y planes, as well as the support time on the DPA. During the DPPT, a so-called postural priority index was calculated, which is "the quotient of the mean tilt of the DEB platform from the horizontal plane (in degrees) and the postural instability calculated as the mean of the absolute displacement around the resultant mean axis (in degrees, measured with an accelerometer in the sternal position)" (Jadczak *et al.* 2019). Respectively, in the 3 trials, a higher score (longer time, higher pp score) meant better postural control. Additionally, the following values were adopted for PP scores: > 60% normal visual-proprioceptive control; 40–60% indicated faulty visual-proprioceptive postural control, < 40% indicated vestibular (failure) control.

Functional tests

The athletes performed two tests; the "Counter Movement Jump" (CMJ) followed by the "3 Single Leg Hops Test" (3SLHT). The parameters of both tests were recorded with the Optojump system (Microgate, Bolzano, Italy).

In the first trial, ground contact time [s], flight time [s], jump height [cm], generated power [W/kg], and acceleration [m/s] were measured. Subjects performed 3 repetitions as follows: assuming a starting position with hands placed on the hips, bending knee joints to approximately 90°, performing a maximum vertical jump, and landing. Then the competitor assumed the starting position again while waiting for the signal indicating the next repetition.

The 3SLHT test involves performing three jumps consecutively on one leg. The goal is to achieve maximum distance without losing balance and to achieve a stable landing after each jump. The athletes were instructed by the instructor to perform the next jump only after regaining balance. The distance was measured from the heel at the starting line to the heel of the limb being tested. The distance performed [cm], flight time, and contact time [s] were measured for each limb. The test result – length, was then divided by the subject's height to obtain a relative score.

Fundamental movement evaluation

The Functional Movement Screen (FMS) test was conducted according to generally accepted procedures and using original equipment. (Kiesel *et al.* 2007). A set of 7 movement patterns were performed. Each test was scored on a scale of 0–3, where 0 means that the test subject reported pain during the movement, 1 point means that the test subject was unable to perform the movement, 2 – performance of the movement with compensation, 3 – perfectly performed movement without compensation, with full postural control in the maximum ranges of mobility. The tests were performed in a set order and according to generally accepted standards described in the literature (Lockie *et al.* 2015).

Injury questionnaire

An online survey was completed by every player to collect data on musculoskeletal injuries sustained during the last round of the season. The FIFA standard questionnaire (Fuller *et al.* 2006) was used to record football-related injuries. Then, all injuries resulting from the questionnaire and the players' consultation/therapy at a medical facility were summed.

Statistical analysis

All analysed outcomes were presented using median, minimum, and maximum values. Normality of the variables' distribution was tested using the Shapiro-Wilk test and asymmetry coefficients were determined. If the normality was not met, the between-group differences were tested using the non-parametric Mann-Whitney U test, for players who sustained an injury (yes) and who did not sustain an injury within the tested season (no). The effect size was calculated and interpreted using values of Cohen's d such as small (0.2), medium (0.5) and large (0.8). For all statistical procedures, statistical significance was set at alpha 0.05. Statistical analysis was performed using the Jamovi program version 1.6.23.0.

Result

In the study group (n = 46), 18 female athletes suffered from an injury (including one person with two injuries). Seven ankle injuries, six knee injuries, and the same number of lower limb muscle injuries were recorded. Table 1 shows the descriptive characteristics of the two groups – uninjured ("No") and injured ("Yes") with respect to age, height, weight, BMI, CMJ test, 3SLHT, FMS, strength, and power of extension and flexion for the right and left leg. A significant difference between groups was achieved for the following tests and anthropometric measurements: age ($p = 0.001$), height ($p = 0.018$), weight (<. 001), BMI (< .001), 3SLHT test for left ($p = 0.044$) and right leg ($p = 0.001$), FMS ($p = 0.026$), flexion power/kg ($p = 0.039$) and for the maximum time without contact test on DELOS platform for left leg ($p = 0.022$). At least medium values of effect size were noted for age, weight, BMI, and 3SLHT_R.

Table 1. Group descriptives.

	Group	N	Median	Min.	Max.	Shapiro-Wilk test p	Statistic	p	Effect Size
Age	No	28	13.0	9	24	**<.001**	**110.0**	**0.001**	0.56
	Yes	18	20.5	11	28	0.454			
Height	No	28	159.0	140	177	0.643	146.5	**0.018**	0.42
	Yes	18	167.0	158	176	0.319			
Weight	No	28	48.5	27.3	76.0	0.887	103.0	**<.001**	0.59
	Yes	18	60.0	48.0	80.0	0.200			
BMI	No	28	18.9	12.8	24.8	0.973	86.0	**<.001**	0.66
	Yes	18	21.5	19.2	27.3	0.018			
Power_CMJ [W/kg]	No	28	12.8	10.7	17.0	0.275	241.5	0.822	0.04
	Yes	18	12.9	9.96	14.9	0.972			
3SLHT_L_(length/height)	No	28	2.6	2.0	3.0	0.481	162.0	**0.044**	0.36
	Yes	18	2.8	2.2	3.8	0.544			
3SLHT_R_(length/height)	No	28	2.5	2.2	3.2	0.053	114.0	**0.001**	0.55
	Yes	18	2.95	2.1	3.6	0.785			
FMS	No	28	17.0	16	20	**<.001**	183.0	**0.026**	0.27
	Yes	18	17.0	15	18	**0.001**			
Right_Extension_Power/KG	No	28	1.5	0.94	2.6	0.118	195.0	0.206	0.23
	Yes	18	1.7	1.02	2.2	0.742			
Left_Extension_Power/KG	No	28	1.4	0.86	2.2	0.169	207.0	0.320	0.18
	Yes	18	1.6	0.72	2.5	0.994			
Right Flexion_MOC/KG	No	28	0.9	0.27	1.4	0.135	183.5	0.126	0.27
	Yes	18	0.96	0.65	1.4	0.312			
Left Flexion_MOC/KG	No	28	0.8	0.37	1.3	0.253	160.0	**0.039**	0.37
	Yes	18	0.9	0.57	1.7	0.276			
L_Max. t. without cont. (s)	No	28	10.9	1.8	30.0	**0.023**	149.5	**0.022**	0.41
	Yes	18	18.9	8.2	30.0	**0.024**			
P_Max. t. without cont. (s)	No	28	12.6	2.4	30.0	**0.002**	189.0	0.159	0.25
	Yes	18	16.6	2.5	30.0	0.387			
L_PP (%)	No	28	53.3	0.9	94.7	**0.010**	220.0	0.478	0.13
	Yes	18	49.0	1.1	73.3	0.063			
P_PP (%)	No	28	52.4	1.9	89.6	**<.001**	202.0	0.265	0.20
	Yes	18	46.3	2.4	69.8	0.600			

Discussion

The main purpose of this study was to analyse the differences in preseason biomechanical evaluation outcomes between injured and non-injured female football players. The group of the players who sustained an injury reported to be significantly older, higher, weightier, and had higher BMI values in comparison to the non-injured players. Additionally, the footballers who scored higher values in the jump test on the right leg also reported injuries that occurred during the football season.

Several studies have identified BMI as a factor, and a higher score was associated with an increased risk of approximately 1.43–1.51 times (Brumitt *et al.* 2020). Similar conclusions were reached by authors with a study group consisting of adolescent and young football players (Richmond *et al.* 2012, Kemper *et al.* 2015, Brumitt *et al.* 2020), as well as in professional female football players

(Nilstad *et al.* 2014). However, these results do not align with work such as Ostenberg's (2000), where anthropometric measurements (except for age) were not significantly different between the two groups (Ostenberg *et al.* 2000). Additionally, the correlation between BMI score and injuries has led researchers to hypothesize that there is an optimal range of body fat for an athlete and that increased body fat is associated with more injuries, especially overload injuries. (Kemper *et al.* 2015). The increasing number of injuries with age may be related to factors such as increased intensity and frequency of training, as well as game involvement and level. In addition, it has been noted that a faster introduction of young female players to the senior ball was associated with an increased risk of injury (Ostenberg *et al.* 2000).

The athletes capable of better performance were more frequently injured. This is a result opposite to previous results in this topic, where more often than not, the better jumping ability was associated with fewer injuries (Iguchi *et al.* 2016) or no differences were shown between groups (Ostenberg *et al.* 2000, Brumitt *et al.* 2020). The opposite results could have been expected, as a better score in the 3SLHT test is theoretically associated with better dynamics and motor coordination, and the test results themselves are often used to monitor the progression of, for example, ACL reconstruction patients. Thus, there is an option to develop tests using the Optojump platform, which excludes human measurement error, and also the procedure is performed in the same way each time to verify the results of this test.

The FMS as a screening test is used in clinical and sports practice (Moran *et al.* 2017) to determine asymmetries as well as limitations in ranges of motion. It allows the detection of deficits in the kinematic chain during the execution of basic movement patterns. The evidence provided by the FMS test results in a group of athletes is described as small/insufficient in determining injury risk (Bonazza *et al.* 2017, Moran *et al.* 2017). There is also a deficit of information regarding the use of the FMS test in female groups, as previous work has focused primarily on the male gender, which has been identified as a limitation of the study (Bonazza *et al.* 2017). In our sample, female athletes who sustained an injury recorded a lower FMS score and achieved a maximum lower score (18) compared to the uninjured group (20). Similar results have been reported in a group of professional female basketball players, where the test score was significantly associated with injury risk (Šiupšinskas *et al.* 2019).

Of the isokinetic strength results, only the measurement of knee joint flexor strength was found to be significant. Usually, papers on similar topics convert the results into hamstring-to-quadriceps (H/Q) ratios or LSI (limb symmetry index). Unfortunately, we did not find papers using this sample where the results were presented in the same form as in our study, so it is hard to compare the results of other authors. We can only state that if the H/Q ratio was calculated then impaired flexor strength would fit into the theory of using this ratio to determine predisposition to injury, and this topic has already been widely reported in the scientific literature, and it is still under discussion (Grygorowicz *et al.* 2017, Lee *et al.* 2018). It is worth noting that the isokinetic test does not reproduce the conditions on the playing field, which significantly weakens the value of this test. It is also an open kinematic chain, where, however, the football player works in a closed chain all the time. This would seem to be an obvious variable to influence injury, however, research does not support links between muscle strength and lower extremity injuries (Steffen *et al.* 2016).

The balance/neuromuscular control test on the DELOS platform was also found to be statistically significant. The injured group had significantly worse results in the tests where the maximum time in single-leg standing and the postural priority score were measured. However, this is the opposite result with the work of authors such as Soderman and

Ostenberg (Ostenberg *et al.* 2000, Soderman *et al.* 2001), where female athletes with a better level of proprioception were more likely to be injured. Namazi *et al.* also do not support our results. They showed no association between proprioception testing and lower limb injuries (Namazi *et al.* 2019). This also contradicts the results of observing the effect of proprioceptive training on injury prevention. Typically, there was a significant decrease in injuries in the group after the above intervention (Riva *et al.* 2016, Whalan *et al.* 2019).

A well-thought-out work plan for the preparatory period enables one to achieve the best possible results in terms of speed and strength, among other things, and to reduce the risk of suffering an injury (Ishøi *et al.* 2020). The literature provides evidence of the effectiveness of screening tests as well as the association of selected risk factors (previous episodes, poor proprioception, or joint instability) with injuries (Ishøi *et al.* 2020). Proper identification of potential risk markers provides a foundation for injury prevention (Vianna *et al.* 2021) and also provides an opportunity to develop new prevention programs. Studies such as these provide an opportunity to identify them, as well as the possibility of discovering new associations for future prospective studies and prevention programs (Namazi *et al.* 2019).

Study limitations

The strengths of this study are mainly the conduct of injury classification according to the FIFA Consensus Statement and the number of studies included in the BOF (4). On the other hand, important limitations of this study are the lack of data accounting for injury referral per unit time (e.g., X/1000h), training load during the season, and the small number of female participants, and most importantly the retrospective collection of injury data where there is a risk of missing an event. It is also worth comparing the injury history of female athletes, which is the greatest risk factor for sustaining an injury (Crossley *et al.* 2020).

Conclusions

There are significant and clinically relevant differences between the uninjured and injured groups of female soccer players in respect to different biomechanical and functional parameters recorded in the preseason evaluation. The footballers who scored higher values in the jump tests and FMS tests reported injuries that occurred more often during the football season. Additionally, the injured players were older, higher, weightier, and had higher BMI when compared to the non-injured players. In future, more powered sample size studies, based on prospective injury data collection should be performed to verify whether these potential differences in the pre-season outcomes can be used as injury risk identifiers.

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