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The Relationship between Symmetrical and Asymmetrical Jumps and Their Influence on Speed Abilities: Gender Consideration

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Abstract: Purpose: Plyometric exercises, in the form of jumping, are extreme physical activities. The aim of the study was to determine how symmetrical-single versus asymmetrical-continued plyometric exercises differ between men and women and affect speed abilities. Methods: Twenty-two healthy females and forty-four males from different sports practices participated in the investigation. The countermovement jump (CMJ) and drop jump (DJ) of 40/60 cm box were performed on two independent and synchronized force platforms (Bilateral Tensiometric Platform S2P, Ljubljana, Slovenia). The measurement of a standing long jump (SLJ) and all continuous jumps: standing five jumps (SFJ), standing bounce triple jump (SBTJ), five double-leg jumps (FD-LJ), and a 10 m horizontal single leg jump (HSLJ-10mL/R) were performed using OptoJump–Next Microgate (OptoJump, Bolzano, Italy). Results: Statistically significant differences were noted in all jump kinematic and somatic parameters, in favor of the men. The correlations between values of height of symmetrical jumps (bilateral) and distance (SLJ) were stronger in women despite the shorter jumps than the men. When an alpha-level of 0.01 was set, this study demonstrated a stronger correlation between symmetrical-single and asymmetrical-continuous plyometrics exercises and sprints, both men and women. This relationship is due to their similar kinematic and dynamic structures with sprinting steps. Conclusions: The results showed a large dispersion of the relationship ($p < 0.05$) between jumps and sprints divided into 10, 20 and 30 m, both in men and women. Both types of exercises implemented as a plyometric training regime are an extremely important tool for sprint speed development.

Keywords: plyometrics activities; sprint; vertical jumps; horizontal jumps; elastic energy; kinematics

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1. Introduction

The analysis of biomechanical asymmetry in the structure of a sports movement is useful in terms of performance and injury risk assessment [1–3]. According to Bishop et al. [4] and Madruga-Parera et al. [5], functional asymmetry between the limbs refers to the differences in the performance of the movement structure of one limb in relation to the other. Therefore, the asymmetry is not uncommon in basic locomotor activities such as walking and running. For example, during walking, asymmetry might be defined as the difference between left and right limbs in spatio-temporal characteristics of the single step [6,7]. This information can help give insight into the asymmetry of individual joints within the limbs, assess possible power balance disorders, and above all, improve the performance of one limb over the opposite limb through appropriate sports training [8]. Knowing the asymmetry of the step in walking and running will allow the better understanding of the functional asymmetry which also occurs in jumping. Such knowledge will enable the use of asymmetry as a factor assessing the mechanical efficiency of individual limbs in jumping. This, in turn, will allow the application of proper training, and the development of jumping skills.

However, during jumping activity bidirectional forces make the asymmetry assessment a more complex task. This asymmetry is better recognized as unilateral (one leg take-off/landing) and bilateral (double leg take-off/landing) assessment of single-leg jumps, starting from a standing position [9–13]. It includes the countermovement jump (CMJ) [14,15] and squat jumps (SJ) [15,16]; standing long jump (SLJ) [17–19] and drop jumps (DJ) from certain heights [14,15]. This symmetry covers all kinematic and dynamic aspects that differentiate each limb during the performance of a given exercise in the take-off/landing phase. Most of these jumps are executed in the vertical directions, however, SLJ is executed in the horizontal direction [20–23]. Additionally, limb asymmetries have also been measured in continuous type jumps, including: a standing triple jump, a standing five jump, standing 10 jump, or multiple jumps on one leg or alternating. In all these jumps vertical and horizontal forces are applied [14,24,25]. These asymmetric jumps use a one limb take-off and landing movement [26–29], and apply the pre-activation reflexes (the previous jump) which are very important for the effectiveness of eccentric-concentric contractions [26]. This pre-activation determines the first contact of the foot with the ground. Asymmetric jumps seem to be best for duplicating forces in the landing and take-off motion structure where certain movements must be performed at high speeds (e.g., ankle action during sprints, take-offs in long jumps, high jumps, or triple-bounce jumps). The sum of the force or power generated by each limb acting separately may be greater than the force generated during bilateral movement in, which both limbs act simultaneously [28–32].

The differences observed in the assessment of jumps, regardless of the type: symmetrical-single, asymmetrical-continuous, horizontal or vertical, between women and men can be interesting phenomenon in the analysis of the results achieved, in almost any sport. Numerical evaluation of even the smallest variable, especially anthropometric, and assessing the level of explosive power of the lower limbs between the sexes, may influence the training procedure in the field of motor development and injury prevention. It can also be a tool for talent identification, especially in sport, where it is required to perform dynamic movement structures such as jumps. There are several publications comparing jumps in terms of gender [33–37], although this was mainly related to vertical jumps (CMJ DJ, SJ). In their research, Abian et al. [38] showed a difference of as much as 10 cm between men and women during a vertical jump. Such a great difference results from the strength of the lower limbs [39]. The performance of the optimal vertical jump depends mainly on the vertical speed at the moment of take-off, which is correlated with the explosive power generated during this task [40]. During the take-off it is required to generate as much force as possible, therefore men cope with execution of this specific task better than women [38,41,42]. However, according to Komi and Bosco [43], women seem to make better use of energy transfer. They applied a greater percentage of the energy stored during the pre-stretching phase of a jump than men.

The initial acceleration and maximal speed over a relatively short distance of 5–30 m are essential factors in the aforementioned sports [26,44–46]. Spencer [47] found that the average length of sprints in football (European Champions League) is 5–20 m; the number of these sprints is 200–260. Top basketball players perform 150–180 sprints over a distance of 5–8 m [48], similar values are presented in handball [49]. Top tennis players average 180–230 sprints over a distance of 5–15 m [50]. Different physiological aspects effect on sprint performance during acceleration and maintenance of top speed. For example, concentric force and the rate of force development have an impact on early acceleration [51]. The primary criterion for effective sprint acceleration is the smallest impulse of force in the braking phase and the largest impulse in the propulsion phase [52]. The average step contact time in the first 10 m of starting acceleration is 120–160 milliseconds for top athletes [53]. The production of ground reaction forces in acceleration, such as a short 30 m sprint depends primarily on the motor ability of the lower extremities. In turn, these abilities must be trained through specific exercises, where both: internal and external structures of movement are close to the sprint movement, with a maximum intensity, over a 5–30 m distance.

Based on the discussion above, the aim of the study was to determine how symmetrical-single versus asymmetrical-continued plyometric exercises differ between mand and women, and affect speed abilities. The gender aspect has been introduced to show whether these jumps have a different effect on speed when men and women are considered. Because women use a larger percentage of the energy stored during the pre-stretching phase of jumps than men [43] it was hypothesized that symmetrical jumps (bilateral take-off) would show a stronger relationship with the speed performance in women than in men.

2. Material and Methods

2.1. Somatic Measurement

Standing body height was measured with the head positioned in the Frankfurt plane using a fixed wall-mounted and stadiometer GPM (DKSH Switzerland, Ltd., Zurich, Switzerland) and recorded to the nearest 0.1 cm. Body mass was measured on a calibrated digital scale (Seca 862, Liverpool, UK) with accuracy of 0.1 kg. All anthropometric measurements were taken twice by a trained specialist in the morning 1 day before testing in a biomechanical laboratory. Additionally, body mass index (BMI-kg/m^2) has been calculated.

2.2. Experimental Design

The purpose of the current study was to compare the effects of symmetrical and asymmetrical—continuous plyometrics exercises on the maximal running speed between men and women in different sports. The subjects were assigned to two groups, one male and one female. The data collection was done at the biomechanical lab and the indoor hall on a synthetic track, according to the type of measurement. Each session lasted four hours, during one week, according to the participant's schedule. The participants were asked to refrain from any sports activities 48 h before testing. Each participant performed a warm-up composed of light jogging, flexibility, and light jumping and sprinting at the place of measurement. All participants completed a familiarization protocol and testing procedure. All measurement sessions were in the same order. On the first day, there was a measurement of symmetrical-single jumps on a tensiometric platform in the biomechanics laboratory. On the second day, there were asymmetric-continuous jumps measurements, but due to the heavy load on the lower limbs in the first day, only three jumps were performed. On the next day, 10 m in R/L leg on time jump was measured. This jump in its performance resembles a single sprint step. Its application allowed to bring this motor structure closer to the next attempts-sprints. The sprint runs took place on the fourth day of the research.

2.3. Subjects

Twenty-two healthy females and forty-four males participated in the investigation (age = 20.18 ± 1.27 years and 21.26 ± 1.78 years, body mass = 62.23 ± 7.02 kg and 78.49 ± 7.94 kg, body height = 166.78 ± 5.29 cm and 182.18 ± 6.32 cm (respectively). The subjects were second-year students with different sports backgrounds. Student-athletes were recruited from a variety of sport clubs (university and local sports). They mostly participate in track and field, soccer, tennis, handball, judo, basketball, and volleyball. The inclusion criteria were as follows: regular participation in organized sports training (4–5 times weekly), to have previous experience in plyometric and ballistic types of exercise, and they were free of any neuro-muscular or skeletal injuries of lower limbs at the time of the recruitment. They received detailed information regarding the study aims and investigation protocol. All participants signed a written informed consent in accordance with the Declaration of Helsinki-Tokyo. The study protocol was approved by the Human Ethics Committee of the University of Ljubljana (ID: 14_2019-1436).

2.4. Testing Protocol

2.4.1. Symmetrical—Plyometric Exercises Measurements

The symmetrical-single jumping exercises (CMJs, DJs) and SLJs were measured during one testing set. Before the test, the participants were informed of how the tests would proceed and were given a demonstration of the task. An appropriate warm-up was allowed before the jumping began. The following order of jumps: CMJs, DJs, then SLJs. The CMJs and DJs were performed on two independent and synchronized force platforms (the Bilateral Tensiometric Platform S2P, Ljubljana, Slovenia). DJs were assigned from two heights (40 cm for female and 60 cm for male on a special platform. The measurement of standing long jump (SLJ) was performed using OptoJump–Next Microgate (Optojump, Bolzano, Italy). When performing CMJ, there are no knee angle restrictions during the eccentric phase of the jump with an additional dynamic two-arm swing. To initiate the drop jump (DJ), participants were instructed to "step out" from the edge of the platform. During the dropping movement, participants held upper limbs in control position—along the body. The landing was simultaneously on both feet. This was followed by a dynamic jump up—the classic CMJ with arm swing. In turn, in the standing long jump (SLJ), the subject stands behind a line, feet slightly apart. A two-foot take-off and landing were used, with arms swinging and knees bent to provide forward propulsion. The subject tries to jump as far as possible, landing on both feet without falling backwards. In both jumps, the height and length of the jump was measured up to 1 cm. Each test was performed three times. The best result was selected for further analysis. Participants had a 1-min break between repetitions. The breaks between tests were between 3 min in duration. The participants were instructed to perform for maximal height and maximal distance (length).

2.4.2. Asymmetrical—Plyometric Exercises Measurements

Due to the fact that such jumps require space to perform, they were implemented in the athletics hall with a synthetic surface. Only three jumps were performed in one session, in the following order: standing triple jump (STJ), standing bounce triple jump (SBTJ), and standing double-leg five jumps (FD-LJ). The measurements were performed using OptoJump–Next Microgate (Optojump, Bolzano, Italy). The starting position for the STJ and FD-LJ was similar as for SLJ. In STJ, the participant was positioned with feet together at the starting line. The subject proceeded to carry out the triple jump by taking-off with both feet, landing on one foot, pushing-off again, landing on the other foot, pushing-off a third time, and landing on both feet on the light mattress. In turn, the SBFJ is similar to the classic triple jump, except that the first jump (initiation of jump) was performed off a box at a height of 25 cm. The participant executed the take-off by pushing-off with both feet, then landed on one foot on the track, then the other foot, pushed-off again, and landed with both feet. The result was the distance from the edge of the box to the landing. All three jumps landed on both feet on the light mattress without falling backwards. The result was the sum of three jumps, nearest to 1 cm. The break between each jump lasted about 1 min and 6 min between the different jumps. Three trials were executed for each jump and the best jumps were taken for calculation.

In turn, lower limb reactive power jumps were measured at the next training session. It included two jumps: a 10 m horizontal single leg jump—left or right leg [24]. The testing was performed using the Brower Timing System (Brower, Houghton, IA, USA). Two photocells were positioned at the start and at the end of the 10 m section. The participant was positioned at the starting line with left/right foot, then pushed-off with the left/right foot and tried to overcome the distance of 10 m in one-legged jumps in the shortest possible time. Participants performed three trials in each condition, the best was taken for statistical analysis. A 2 min rest was provided between each trial, and 6 min. between each jump modality.

2.4.3. Running Speed Assessment

The 10, 20 and 30 m sprint time from standing start were used in current investigation. The sprint was performed on an indoor track using the Brower Timing System (Brower, USA) device. Four pairs of photocells were positioned at the start and at 10, 20 and 30 m section lines, respectively. The time was recorded from passing the first photocells until the sprinters crossed the 10, 20 and 30 m finish line. Before speed testing, participants performed a warm-up of light jogging, stretching, and sprint drills. The participants were instructed to sprint as fast as possible across the entire section. Two trials were performed, of which the fastest time for each section was used for further analysis. The times were recorded with a precision of 1/100 of a second. The sprints were separated by a 3 min break.

2.5. Statistical Analysis

Descriptive statistics (mean, SD) were calculated for all dependent variables. The data were tested for normality using the Shapiro–Wilk test. To test for differences in dependent variables, linear analysis of variance (ANOVA) models was applied. The test–retest reliability of all dependent variables was evaluated by intraclass correlation coefficients (ICC). Effect sizes were evaluated by calculating Cohen's d with 95% confidence intervals [48]. Cohen suggested that d = 0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size, and 0.8 a 'large' effect size. The Spearman rank correlation coefficients was used to assess relationship between jumps and sprints. The criterion for statistical significance was set at an alpha-level of 0.05 and 0.01. Data analysis was performed with SPSS for Windows 15.0 (IBM, Armonk, NY, USA).

3. Results

A gender analysis has shown the statistical differences between men and women in the sample. Significant differences between the sexes were observed in all selected somatic variables: body height, body mass and BMI. The men outperformed the women (Table 1).

Table 1. Descriptive statistics of selected anthropometric characteristic of female and male athletes.

Variables		No	Mean	Std. Deviation	95% Confidence Interval		F	*p*	d
					Lower Bound	Upper Bound			
Age [year]	Men	44	20.29	1.32	20.20	21.64	3.541	0.0039	1.55
	Women	20	21.18	1.29	20.50	21.91			
Body height [cm]	Men	44	182.19	6.43	180.23	184.14	87.573	0.000	2.56
	Women	20	166.78	5.29	164.30	169.26			
Body mass [kg]	Men	39 *	78.65	7.09	76.35	80.95	69.974	0.000	2.34
	Women	20	62.23	7.21	58.86	65.61			
Body mass index [kg/m^2]	Men	39 *	23.36	1.59	22.84	23.88	4.227	0.044	0.47
	Women	20	22.28	2.39	21.17	23.40			

p = *p*-value, d = Cohen's d, F = value when ANOWA, * five men missed the body mass measurement, then the number of BMI changed.

Table 2 presents a comparison of selected symmetrical—single jump exercises and asymmetrical—continuous jump exercises based on a kinematic comparison: height or distance or time, between men and women. In the DJ, women jumped from a 40 cm box and men from a 60 cm box. Statistically significant differences were noted in all jump parameters, which considering the DJ and CMJ height of the jump, was 4 cm and 10 cm, respectively, higher for men. The differences in distance in SLJ was 7.94% in favor of men. The reliability of the symmetrical jumping tests was measured, applying an intraclass correlation coefficient (ICC). This indicated that the height for the DJ test (ICC = 0.90) and the CMJ (ICC = 0.95) and the distance jumped for the SLJ (ICC = 0.91) reached high reliability. In turn, a significant difference $p = 0.00$ occurred in all five jumps from the asymmetrical-continuous jumping group. The highest percentage difference between women and men showed in the 10 m horizontal single leg jump (16.66 s and 16.73 s, respectively for the left and right limbs), in favor of men. In other jumps: STJ, SBTJ, and FD-LJ the difference did not exceed 8%. As in the previous jumps tests, reliability of the asymmetrical (horizontal) jumping was calculated, using intraclass correlation coefficient (ICC). The calculation showed that distance jumped for SFJ test (ICC = 0.95) and SBFJ (ICC = 0.90) and FD-LJ (ICC = 0.88) reached a high reliability.

Table 2. Descriptive statistics of selected plyometric exercises—jumps executed in symmetrical and asymmetrical manner.

Exercise		N	Mean	Std. Deviation	95% Confidence		F	*p*	d
					Lower Bound	Upper Bound	Between Groups		
DJ [m]	Men	44	0.29	0.06	0.27	0.31	7.252	0.000	0.74
	Women	20	0.25	0.04	0.23	0.27			
CMJ [m]	Men	44	0.38	0.07	0.36	0.39	28.49	0.000	1.57
	Women	20	0.28	0.05	0.26	0.30			
SLJ [m]	Men	44	2.62	0.18	2.56	2.67	1.18	0.000	3.03
	Women	20	2.15	0.09	2.10	2.20			
FD-LJ [m]	Men	44	13.12	0.94	12.84	13.41	102.70	0.000	2.77
	Women	20	10.78	0.64	10.47	11.08			
SFJ [m]	Men	44	7.45	0.54	7.23	7.61	92.48	0.000	2.66
	Women	20	6.15	0.38	5.97	6.33			
SBTJ [m]	Men	44	7.41	0.55	7.24	7.58	58.95	0.000	2.11
	Women	20	6.35	0.41	6.17	6.55			
HSLJ-10mL [s]	Men	44	2.34	0.14	2.29	2.38	82.66	0.000	2.46
	Women	20	2.73	0.20	2.64	2.82			
HSLJ-10mR [s]	Men	44	2.33	0.15	2.29	2.38	82.536	0.000	2.48
	Women	20	2.72	0.18	2.64	2.80			

DJ—drop jump, CMJ—countermovement jump, SLJ—standing long jump, FD-LJ—five double leg jump, SFJ—standing five jump, SBTJ—standing bounce triple jump, HSLJ-10mL/R)—10 m horizontal single leg jump, *p* = *p*-value, d = Cohen's d, F = value when ANOWA.

Table 3 represents a comparison of selected sprint running times for three different distances 10 m, 20 m, and 30 m between men and women. The men showed significantly better times ($p = 0.000$) than women in all three sprints. As the distance lengthened, the differences between the groups increased. The biggest difference was in the 30 m run and was 0.52 s (12.09%).

Table 3. Descriptive statistics of selected sprinting performance: 10, 20, and 30 m.

Sprint		N	Mean	Std. Deviation	95% Confidence		F	*p*	d
					Lower Bound	Upper Bound	Between Groups		
SPRI 10 m [s]	Men	44	1.84	0.09	1.81	1.87	45.79	0.000	1.49
	Women	20	2.01	0.09	1.96	2.05			
SPRI 20 m [s]	Men	44	3.11	0.13	3.07	3.15	91.72	0.000	2.52
	Women	20	3.44	0.14	3.38	3.50			
SPRI 30 m [s]	Men	44	4.30	0.17	4.25	4.35	128.20	0.000	3.11
	Women	20	4.82	0.17	4.74	4.90			

SPR 10—10 m sprint, SPR 20—20 m sprint, SPR 30—30 m sprint, *p* = *p*-value, d = Cohen's d, F = value when ANOWA.

Only four jumping exercises showed a significant relationship $p = 0.05$ (Table 3) with sprints on three different distances, both: two in women (10/20 m with SLJ) and two in men (10/20 m with SBTJ). In the analysis with the significance set at $p = 0.01$, the greater number of jumps showed a relationship with sprints at 10/20/30 m, mainly with jumps from the continuous group in men (Table 3). There were no relationships between the DJs and sprints in both groups, except for one, DJ-60 and 30 m in men ($p = -0.437$ at $p = 0.01$).

4. Discussion

The goal of our study was to determine how symmetrical and asymmetrical plyometric exercises, implemented as a single jump and continuous jumps related to speed ability (initiation of movement, acceleration, and maximum speed) differ between gender. The results showed a large dispersion of the relationship between jumps and sprints divided into 10, 20 and 30 m, both in men and women. This did not confirm the generally accepted principle that symmetrical-single jumps will show greater correlation with the initial acceleration (10 m), and asymmetrical jumps-continuous are combined with a 30 m run.

4.1. Symmetrical-Single Plyometric Exercises Performance

Symmetrical-single plyometric exercises improve the function of eccentric-concentric lower extremity function and muscle stiffness. In addition, these jumps are one of the most important diagnostic tools for evaluating an athlete's push-off force [9,54,55]. Research has shown, that these exercises have a high correlation between vertical jumps and sprint speed [26,47,49,56,57]. However, the results from our experiment partly contradict this finding. There was no relationship between the 10 m sprint and all three individual jumps taken from standing position. The countermovement jump (CMJ) showed a single characteristic that correlated to the 20 and 30 m sprint in women (r = 0.559 and r = −0.591 at $p = 0.05$ and 0.01 respectively) (Table 4). The men only showed interaction with the 20-m sprint.

Table 4. Comparison of the Pearson correlation coefficients calculated for all motor parameters at $p < 0.05$ and $p < 0.01$.

Male			Exercise	Female		
30 m	**20 m**	**10 m**		**10 m**	**20 m**	**30 m**
−0.437 **	0.290	−0.253	60 DJ 40	−0.057	0.186	−0.146
−0.296	0.403 **	−0.015	CMJ	−0.352	0.618 **	−0.591 **
−0.461 **	0.557 **	−0.181	SLJ	−0.510 *	0.559 *	−0.659 **
−0.500 **	0.473 **	−0.460 **	SFJ	−0.539 *	−0.348	−0.663 **
−0.562 *	0.476 **	−0.416 *	SBTJ	−0.253	0.606 **	−0.453 *
−0.225	0.532 **	−0.451 **	DL-5 J	−0.399	−0.600 **	−0.5.33 **
0.617 **	−0.534 **	0.542 **	HSLJ-10mL	0.239	0.413	0.389
0.606 **	−0.492 **	0.465 **	HSLJ-10mR	0.437	−0.354	0.641 **

* significant correlation $p < 0.05$, ** significant correlation $p < 0.01$.

In turn, the DJ-40 and DJ-60 showed no relationship, not only for 10 m but also for 20 m. Only men showed a relationship with 30 m, $p = -0.437$, but at $p = 0.01$ (Table 4). These results contradict the research of Maulder [58] and Marković and Mikulić [27], who showed a significant correlation between drop jumps and sprint speed. The neuromuscular mechanisms involved in performing the drop jump and sprinting step are very similar. The faster the elongation of the muscular tendon complex, the shorter the time and the greater the amount of elastic energy. Therefore, the DJ should have a stronger relationship to sprint speed over longer distances [59]. It is a well-known fact, that the musculoskeletal complex (the calcaneal tendon, m. gastrocnemius medialis, m. gastrocnemius lateralis and m. soleus), under conditions of higher velocity of the eccentric-concentric cycle, can store more kinetic energy in the form of elastic energy [60–62]. Part of the elastic energy is available for only 0.160–0.180 s, i.e., for the duration of the muscle fibers-actin/miosin crossbridges [60–62]. Elastic energy generation also means shorter contact times, which is a decisive factor in sprint acceleration. In the case of explosive motor structures, including sprinting, the time available to generate force is one of the most critical limiting factors. Probably the contact times in this study were, on average, shorter than 0.200 s, therefore did not otherwise show a statistically significant association values with sprint acceleration [63,64]. However, their values did ensure the effective performance of drop jumps. These are indisputably an essential means of sprint acceleration training.

Contrary to this the SLJ showed a statistical relationship with either 10, 20 and 30 m sprint in both women and men (Table 3). The movement pattern compared with vertical jumps (SJ and CMJ) is different, but the neuro-muscular performance is similar. The force production for the standing long jump and starting acceleration is based on eccentric-concentric muscle contractions. The movement structure of the tasks varies in terms of kinematics and dynamics. A standing long jump is a good indicator of the force gradient [9,32,65–67]. The force impulse value is equal to the area under the force-time curve, and this parameter best defines the distance of the jump and push-off velocity, which is an important parameter of sprint speed. The research results are consistent with those presented by Dobbs et al. [68] and suggested that standing long jump (or horizontal squat jump) may be a useful tool in physiological characteristics relevant to sprint speed and/or early acceleration phase. Surprisingly, the standing long jump was unrelated ($r = -0.181$) to the initial sprint acceleration at 10 m in the male sub-sample. Perhaps, the result at this stage of the sprint was more a reflection of contamination of the running technique than power.

It should be assumed that for women the results in jumps were countermovement is applied reached optimal for them performance, which showed a stronger relationship with sprint than men. Moreover, the men results may indicate that they in their CMJ-measurements did not provide enough energy in the elastic potential of the muscle tendon system. Therefore, the energy stored in muscles and tendons during the stretching phase was poorly transferred to the concentric phase [34]. This in turn influenced the level of their jumping results where CMJ is applied. Consequently, the better association of CMJ-measurement with sprints in women supported our hypothesis that women use a larger percentage of the energy stored during the pre-stretching phase of jumps than men (43). This means that their symmetrical jumps reach the optimal height and optimal length (SLJ).

4.2. Asymmetrical-Countinuous Plyometric Exercises Performance

Asymmetrical-continuous plyometric exercises belong to the horizontal group of jumps and are mostly performed as a unilateral movement, jumps can then progress to bilateral initiation of movement (take-off) [24,32,54,60]. These jumps are an important training tool and, at the same time, a diagnostic method for determining the push-off force to maximize the ground reaction forces of the lower extremities. The sprinter's ability to maximize the ground reaction forces is important [52,69,70]. It was surprise that from continuous jumps only standing bounce triple jump (SBTJ) showed a correlation ($p < 0.05$) with sprint runs (10 and 30 m) and only in men. It seems that men coped better with the technique of this jump, and this was due to the greater power generated by the lower limbs in the reflection of both feet and this directly influenced the result of 7.41 and 6.35 m (for men and women, respectively). No relationship ($p < 0.05$) with any of the three sprint distances in both men and women showed one leg jumps per time. It should be assumed that the times obtained in these jumps were too low (poor jump performance and long contact of the foot with the ground during the jump) to enter into any relationship with, for example, a 10 m sprint. This is probably due to high technical and coordination requirements, which are not all participants of the experiment did.

The correlation appeared when the criterion for statistical significance was set at an alpha-level of 0.01. The movement structure in jumps, especially in HSLJ-10mL/R and sprinting is very similar in terms of muscular contraction. The transition from eccentric to concentric contraction (stretch-shortening cycle) needs to be as short as possible [64,65]. Based on the results in Table 4, we can find that males reach the highest correlation coefficients of two unilateral continuous jumps (HSLJ-10mL/R) between 10 m (r = −0.542; r = −0.465), 20 m (r= −0.534, r = −0.492), and 30 m (r = −0.617; r = −0.617) sprints (Table 4). At the same time, no symmetry between the left and right legs was observed in the sample of our study participants. The mean values of the horizontal jumps at 10 m on the left leg (HSLJ-10mL) and 10 m on the right (HSLJ-10mR) were differ by 0.01 s (2.73 and 2.72, respectively). The same situation could not be found for the female participants. Horizontal jumps on the left and the right leg showed a relatively low association with sprint acceleration. Only one statistically significant association of TEK30mR with SPRI10m (r = 0.641) was found. The test may have been too demanding in terms of the training level of the subjects, or it may have been due to a lack of task performance technique [71,72].

As such, the standing triple jump (STJ) and the bounce triple jump—25 cm (SBTJ) represent unilateral horizontal jumps and are almost similar in performance. In the SBTJ, the beginning of the jump is from atop a 25 cm box, which was to strengthen the accumulation of elastic energy in the first jump, and transfer it to the next two. Both jumps showed high correlation with sprints, especially for men, i.e., 30-m sprint (SPRI30m: SLJ, r = −0 599; SPRI30m: SBTJ, r = −0.562) (Table 4). The results are similar to research of Mackala [25] and Mackala [73]. Sprint acceleration for the 30-m sprint (SPRI 30 m) was also highly associated with the standing triple jump (SBTL, r = −0.663) in the female subsample. For the females, this association demonstrated the highest correlation across all horizontal and vertical plyometric tests with start speed. Both jumps in their performance, showed high efficiency on starting speed. Using these tasks, push-off force is developed, which directly effects stride length. This stride length increases progressively to a distance of 15 m during start acceleration [70,74]. At the same time, step frequency, which depends largely on the contact times of the foot with the ground, increases.

The symmetrical-continuous 5-double-leg jump (FD-LJ) test represents bilateral jumps in the horizontal direction. The movement pattern is different with sprinting, but the neuromuscular performance is similar, based on strong eccentric-concentric muscle contractions. The movement structure of the tasks varies in terms of kinematics and dynamics. Similar to SLJ, this jump can be a good indicator of force and power production [9,32,67]. The force impulse value is equal to the area under the force-time curve. This parameter best defines the distance of the jump and push-off velocity, which is an important parameter of sprint speed. Surprisingly, the standing long jump was related (p = 0.01) to all sprints at 10/20/30 m in the male subsample and in 20/30 m in female.

The basic criterion for effective sprint speed is to maximize the ground reaction forces of the contact phase of the sprinting step as quickly as possible [53,56,66,69,75]. These criteria are intrinsic in the plyometric exercises performed in the experiment. One jump is useful in improving the start and initial acceleration of 5–10 m depending on the requirements of the sport, the other effects the improvement of times on 20 or 30 m. They also depend on type of the sport. All these jumps improve the function of eccentric-concentric lower extremity function and muscle stiffness. The energy stored in the muscles and tendons during stretching is transferred to the concentric phase [27]. This results in a higher speed of movement in the second phase. In addition, these jumps are one of the most important diagnostic tools for evaluating an athlete's push-off force.

However, technically correct execution of the jump does not have to coincide with a better time. The execution time is definitely related to the power involved in performing the jump. It seems reasonable to point out that only the alternating multi-jump, as a classic asymmetric exercise, with a similar execution time compared to a single sprint step, is able to show high relationships with a sprint run of 10, 20 or 30 m. However, the relationship to the listed distances does depend on the distance of the multi-jump. Therefore, based of this experiment, we can conclude that the asymmetrical-continuous jumps had a stronger association with sprint acceleration than the single jumps. The high reliability coefficient indicated that applied symmetrical and asymmetrical jump tests represent consistent performance data among the subjects. This may be explained by the fact that participants are using these types of exercises in their training, and are familiar with proper technique.

One of the limitations was the lower number of women who were examined, which could have influenced the power of statistics. Due to the heavy load on the lower limbs in first day of measurement, on the second day, there were performed only three asymmetrical-continuous jumps. The application of these exercises in sport training may have been too demanding in terms of the training level of the subjects, or it may have been due to a lack of task performance technique. Therefore, caution should be used in their application to avoid injury. In order for the obtained results to have greater application power, further research must be done with a larger number of participants as well as with the application of, e.g., 6 weeks of plyometric training and its influence of speed.

5. Conclusions

The results showed a large dispersion of the relationship ($p < 0.05$) between jumps and sprints divided into 10, 20 and 30 m, both in men and women. This did not confirm the generally accepted principle that symmetrical jumps (single jumps) will show greater correlation with the initial acceleration (10 m), and asymmetrical jumps (continues) are combined with a 30 m run.

The correlations between values of height of symmetrical jumps (bilateral) and distance (SLJ) were stronger in women despite the shorter jumps than the men. Probably women use a larger percentage of the energy stored during the pre-stretching phase of jumps than men, what allow them to reach the optimal height and optimal length (SLJ) of the jumps. It confirms our hypothesis.

However, when the criterion for statistical significance was set at an alpha-level of 0.01 this study demonstrated a stronger correlation between symmetrical-single and asymmetrical-continuous plyometrics exercises and sprints. These correlations apply to both women and men and depend on the type of jump. In this criterion we found that asymmetrical-continuous (unilateral take-off and horizontal direction of movement), had a higher correlation to acceleration than vertical jumps. This relationship is due to their similar kinematic and dynamic structure compare to sprinting step.

When properly integrated into the training process, these jumps are an indispensable means of developing athletes' sprint acceleration in various sports. Their effect is especially important in movement patterns where it is necessary to develop as much speed as possible over a short distance of 5–30 m. At the same time, these jumps are also a reliable and objective diagnostic instrument for planning the power training process of athletes.

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