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Original empirical article

THE CORRELATION BETWEEN EXPLOSIVE STRENGTH AND SAGITTAL POSTURAL STATUS

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Abstract. *The vertical jump is designed to assess the functional performance of the lower extremity (-ies) in both health and injured individuals. The "Myotest" (Myotest SA, Sion, Switzerland), as an instrument, gives us the technology and methodology to assess the abovementioned performance. The "Spinal Mouse" (Quantum Health and Wellness Ltd, Wallasay, England) instrument gives us the technology and methodology to assess postural status, i.e. for the spinal examination of the participants. AIMS: The aims of the actual research were to determine and quantify the variables of explosive strength of the lower extremities and the sagittal postural status of the participants, to determine if there is a significant difference between the variables of explosive strength of the lower extremities, to determine if there is a significant difference between the variables of sagittal postural status, as well as to determine if there is a correlation between the variables of explosive strength of the lower extremities and the variables of sagittal postural status. Nine participants involved in different sport activities constituted the sample, with a body height of 178.00±11.36 in cm, weight of 77.00±13.95 in kg and age of 22.89±1.62 years (Mean±St.Dev.). For the purpose of explosive strength assessment, the participants performed five vertical jumps (CMJ), by using three different protocols of maximum vertical displacement: 1) with a takeoff on the left leg; 2) with a takeoff on the right leg; 3) with a takeoff on both feet. For the purpose of the spinal examination, the participants were positioned in normal standing position. The descriptive statistics showed that the highest values among all the variables of explosive strength were obtained after the CMJ protocol was performed with a takeoff on two feet. In the case of the spinal examination, the descriptive statistics showed a large number of postural deformities. In the case of the correlation between explosive strength and the postural status of the participants, a*

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significant correlation was determined only between certain variables of explosive strength obtained after both CMJ protocols with a takeoff on one leg (left or right) and certain variables of sagittal postural status. The modern way of life strongly influences postural status. When, e.g., the decrease in lumbar lordosis is not followed by an adequate decrease in thoracic kyphosis, the pelvis needs to compensate, ie. change the inclination. If the mentioned compensation is not enough to keep a balanced position of the CG, the patients change the angle in the knee joints. The fact that a correlation between certain variables of explosive strength and certain variables of sagittal postural status was determined, led the authors to the conclusion that a larger sample of participants could point to a more significant correlation. The obtained results could be useful to the participants of the actual research, and all other patients in achieving their goals, which are proper sagittal postural status and adequate muscular potential of lower extremities by application of regular physical activity, and appropriate corrective exercises, determined by experts in the domain of corrective gymnastics.

Key words: *explosive strength, vertical jumping, sagittal postural status, correlation.*

INTRODUCTION

When we talk about body status, we first of all think of the typical body posture, that is, natural body stature which requires the lowest level of energy to maintain. It is well known that man evolved from the squatting, four legged position to the upright position. Upright body posture is the natural, normal and physiologically correct posture. It is a labile body posture with little surface for support and a relatively high centre of gravity. A characteristic of the longest bone segment in the locomotor apparatus, i.e., the spinal column, is that it is vertical in the upright position and is not absolutely upright. There are certain curves, i.e., physiologically normal curves (Milenković, 2007).

The spinal column has a complex structure. On the frontal plane, the vertebrae seem to be placed one over the other. In the sagittal plane, it is obvious that the vertebrae are in the different segments of the cervical, thoracic and lumbar part of the spinal column set up to form the curves called lordosis and kyphosis. From the functional point of view, certain phases of lordosis and kyphosis in all of the segments of the spinal column make the normal upright position possible, that is, the balanced position of the body's centre of gravity. According to the Scoliosis Research Society (SRS), the normal upright posture in the sagittal plane means drawing the line from the cervical (C7) vertebra, immediately before the sacrum promontorium up to the mid-point of the hip joint. In order to talk about the normal upright posture, the aforementioned line could be ±2 cm from the sacrum promontorium. The assumption does not state the absolute number necessary for the balanced position. The influence of the inclined pelvis position, as well as the flexion in the hip joint or knee joint, are connected to the normal upright posture of man (Scoliosis Research Society, n.d.).

Explosive strength is an ability which makes it possible for an athlete to propel his body towards some object or partner. It is especially significant for the athletic disciplines of throwing, the high jump, long jump, and sprint. The expressed explosive strength depends on the percentage and the structure of the motor units of some muscle groups (Bubanj & Branković, 1997). Explosive strength expressed through vertical jumps is defined as the individual ability of the neuromuscular system of the participants to express muscle strain in the shortest time interval (Verhovšanski, 1979).

The Countermovement Jump (CMJ) represents a plyometric exercise for the lower extremities. The aim of using the CMJ jump is to improve the reaction and explosive strength of the lower extremities (Brown et al., 2004). The vertical jump is conceived in such a way so as to assess the explosive strength of the lower extremities of healthy and injured individuals. The "Myotest" as an instrument (Myotest SA, Sion, Switzerland), has the technology and methodology to assess the abovementioned explosive strength (Bubanj et al., 2010). The "Spinal Mouse" (Quantum Health and Wellness Ltd, Wallasay, England) as an instrument has the technology and methodology to assess postural status, i.e., the spinal deformities of the participants (Zsidai & Koscis, 2001).

The aims of this research would be to determine and quantify the variables of the explosive strength of the lower extremities and the variables of sagittal postural status, to determine if there is a significant difference between the variables for the explosive strength of the lower extremities, to determine if there is a significant difference between the variables of the sagittal postural status of the participants, as well as to determine if there is a correlation between the variables of explosive strength of the lower extremities and the variables of sagittal postural status.

METHODS

The sample of participants consisted of 9 healthy students of the Faculty of Sport and Physical Education from Niš (eight of the participants were male and one participant was female), whose body height was 178.00±11.36 (Mean±St.Dev.) in cm, weight 77.00±13.95 (Mean±St.Dev.) in kg, age 22.89±1.62 (Mean±St.Dev.) years, all of whom participated in different sports activities. By using the wireless accelerometer Myotest, the values of the following variables of explosive strength were determined: Height (expressed in cm), Power (expressed in W/kg), Force (expressed in N/kg) and Velocity (expressed in cm/s). By using the "Spinal Mouse" instrument the values of the following variables of the sagittal postural status were determined: KIPNY (binary, expressed by 0 and 1), LORNY (binary, expressed by 0 and 1), SAGSacHip (angle between the sacral bone and hip joint, expressed in deg) and SAGIncl (inclination of the pelvis, expressed in deg). The normal value of the variables SAGSacHip and SAGIncl is 0 deg, and for the variables KIPNY and LORNY, the values 0 and 1 express the non-existence and existence (respectively) of the deformities.

The research was carried out in accordance with the Helsinki Declaration, at the Faculty of Sport and Physical Education in Niš. All of the participants were acquainted with the tasks before the measuring, whereupon they gave their written consent to participate in the project. The research was of a transversal character, that is, there was just one measuring. As part of the measuring, all of the participants had a warm-up period which consisted of a 800 meter slow run, the 4x30 m forward skip, the 4x30m side skip and the 4x30m back skip. After the warm-up, for the purpose of determining the explosive strength of the lower extremities by using the "Myotest", the participants were told to perform vertical jumps (CMJ): first, jumping with a take-off on the left leg, then on the right leg, and finally on both feet. Immediately before the jump, the participants put on a special belt with the wireless "Myotest" device around their waist. The participants performed the CMJ from the initial normal upright position, with their hands on their hips and without a swing (which could influence the vertical jump), through

flexion in the knee joints up to 90°. The jump started after the sound signal, when the participants performed the maximum take off and finally landed with a gentle flexion in the knee joints (up to 110°). After that, the participants took the initial position, that is, the normal upright position, waiting for the new sound signal, when they repeated the aforementioned jumping technique. All of the participants performed the jumps five times. After that, the sagittal postural status of the participants was determined in the following manner: the participants took the normal upright position, and by using the wireless "Spinal Mouse" device, which most authors consider the best in the field, overshot their spinal column from the cervical (C7) vertebra to the sacral (S1) vertebra. The values of the explosive strength variables were read from the display on the "Myotest" device which statistically processed all the values of the given variables and gave their mean value. The values for sagittal postural status were read by the software of the "Spinal Mouse" device, installed in a laptop.

In order to process the given data, the program "SPSS version 13" was used, and the given results can be found in the subsequent tables. The variant analysis was used to determine the significant differences in the values for explosive strength variables, that is, the ANOVA for repeated measures was used. To determine the significant differences in the values of the sagittal postural status variables, the T-test for independent samples was used. In order to determine the correlation between explosive strength variables and sagittal postural status, a correlation was used (Petković, 2000).

RESULTS AND DISCUSSION

The modern way of life has a significant influence, even a negative one, on the explosive strength and the postural status of man. In the case of explosive strength, according to the results of the research conducted by De Boer et al. (2008), the aforementioned influence is most explicit in the occurrence of plantar flexor and knee joint extensor immobilization. When it comes to postural status, according to the results of the research conducted by Horak et al. (1989), in the case of elderly people kyphotic body posture, which is mostly the consequence of osteoporotic changes, requires placement of the body's centre of the gravity in the outmost, ie., limit balanced position and increases the risk of falling, which can be fatal. But, even in the case of relatively healthy people, who do not require outside help, there is a high correlation of badly balanced body posture and fall frequency. In the research conducted by Wu et al. (2002), the authors assumed that age-related changes in type II fiber size and distribution may be related to decreased postural stability and increased incidence of falls among the elderly. The authors do not think that the results of the current research and way of life are related to hypokinesis, because the sample of participants consisted of the students of the Faculty of Sport and Physical Education who are professionally and recreationally physically active, as well as by way of the education process. But the fact is that the participants demonstrated significantly minor explosive strength during the CMJ protocol with a takeoff on one leg (left or right), compared to the CMJ protocol with a takeoff on both feet (tables 1 and 2).

Table 1 The descriptive statistics of the explosive strength and certain sagittal postural status variables.

	N	Minimum	Maximum	Mean	Std. Deviation
HeightL (y)	9	9.98	23.30	16.86	4.35
PowerL (y)	9	22.20	41.90	31.52	6.63
ForceL (y)	9	20.30	26.90	23.19	2.48
VelocityL (y)	9	140.00	212.00	181.11	23.52
HeightR (y)	9	8.97	22.00	16.33	4.08
PowerR (y)	9	19.40	39.40	29.76	5.87
ForceR (y)	9	19.20	26.00	22.58	2.27
VelocityR (y)	9	127.00	208.00	176.78	24.73
HeightLR (y)	9	11.50	43.60	28.96	9.18
PowerLR (y)	9	24.90	65.80	49.08	12.71
ForceLR (y)	9	21.20	37.10	30.21	5.05
VelocityLR (y)	9	148.00	293.00	234.89	41.34
SAGSacHip (y deg)	9	-6.00	11.00	2.44	5.85
SAGIncl (y deg)	9	-7.00	2.00	-2.22	3.27

Table 2 T-test for dependent samples used to compare explosive strength; single measurements of the participants.

	Paired Differences				
	Mean	Std. Dev	t	df	Sig.
HeightL - HeightR	0.53	2.89	0.55	8	0.59
HeightL - HeightLR	-12.09	6.22	-5.83	8	0.00
HeightR - HeightLR	-12.63	5.66	-6.69	8	0.00
PowerL - PowerR	1.77	4.09	1.30	8	0.23
PowerL - PowerLR	-17.56	9.04	-5.82	8	0.00
PowerR - PowerLR	-19.32	7.99	-7.25	8	0.00
ForceL - ForceR	0.61	2.06	0.89	8	0.40
ForceL - ForceLR	-7.02	4.74	-4.45	8	0.00
ForceR - ForceLR	-7.63	3.81	-6.01	8	0.00
VelocityL - VelocityR	4.33	15.44	0.84	8	0.42
VelocityL - VelocityLR	-53.78	26.35	-6.12	8	0.00
VelocityR - VelocityLR	-58.11	20.00	-8.72	8	0.00

The results for explosive strength, as stated above, could be the consequence of the unstable i.e., imbalanced position of the participants, and decreased flexion in the knee joint in the eccentric phase i.e., abbreviated pathway of muscular action during the subsequent extension in the knee joint during the concentric phase. But also, the stated results could be a consequence of the inadequate maximum muscular potential of the lower extremities of the participants. In regards to sagittal postural status, it seems that bad habits related to body posture and to physical inactivity have had a dominant impact on the participants, and that participating in some physical activities has also influenced postural status (table 3).

Table 3 The frequency of the phenomena and the absence of sagittal postural deformities expressed in percentages.

KIFNY (0 or 1)		Frequency	%
Valid	No (0)	4	44.4
	Yes (1)	5	55.6
	Total	9	100.0
LORNY (0 or 1)		Frequency	%
Valid	No (0)	4	44.4
	Yes (1)	5	55.6
	Total	9	100.0

The last statement is in agreement with the research conducted by Kirkham (2002), who concluded that the correlation between sports activities and deformities of the spinal column are particularly noticeable in the adolescent female population. Authors Korovessis et al. (2004) stressed similar conclusions in their research. According to the results of the aforementioned authors, participation in sport activities increased lower back pain among girls ($P < 0.001$). In addition, the incidence of lower back pain was more present among girls in than among boys. In the research conducted by Dejanović & Živković (2008), the authors stated that there are statistically significant relations between anthropometric characteristics and the isometric endurance of the lumbar and abdominal musculature of boys and girls aged 7 to 10, which is a precondition for the occurrence of spinal deformity in the lumbar region of the spinal column. In the research conducted by Axel & McGill (1997), the authors stated that certain exercises for abdominal musculature recruitment, adjusted to suit lower back injury prevention and treatment, sometimes have a negative effect on the lumbar region of the spinal column of the participants due to the excess load to which the aforementioned lumbar region is exposed on that occasion. When a certain postural deformity, the reduction of lumbar lordosis for example, is not followed by an adequate reduction of thoracic kyphosis, the pelvis makes up for it, that is, the pelvis changes the inclination. If this compensation is not enough to keep the human body in a balanced position, which should follow the imaginary line which connects the cervical (C7) vertebra and the sacral (S1) vertebra, there is a change in the angle in the hip and knee joints. The fact that the significant differences in the variables for postural status were not determined between participants with deformities and participants without deformities, apart from kyphosis, for the variable SAGSacHip ($p = 0.01$), shows that the deformities were at a phase which did not influence any significant change in the pelvis inclination and angulation between the sacral bone and the hip joint, but only the compensation in the spinal column (for example, kyphosis for compensatory lordosis and vice versa, tables 4 and 5).

Table 4 T-test for independent samples used to compare the measurings of the sagittal postural status in relation to kyphosis.

	t-test for Equality of Means			
	t	df	Sig.	Mean Diff
SAGSacHip	3.28	7	**0.01**	8.65
SAGIncl	0.57	7	0.59	1.30

Table 5 T-test for independent samples used to compare the measurings of the sagittal postural status in relation to lordosis.

	t-test for Equality of Means			
	t	df	Sig.	Mean Diff
SAGSacHip	1.07	7	0.32	4.15
SAGIncl	-0.61	7	0.56	-1.40

On the basis of the correlation analysis results (table 6), there is a significant correlation between HeightL and KIFNY (negative), PowerL and SAGSacHip (positive), PowerL and KIFNY (negative), ForceL and LORNY (negative), ForceR and KIFNY (negative).

Table 6 The correlation between explosive strength and the sagittal postural status of the participants.

		SAGSacHip	SAGIncl	KIFNY	LORNY
HeightL	Pearson R	0.65	0.13	-0.71	-0.39
	Sig.	0.06	0.74	**0.03**	0.30
PowerL	Pearson R	0.70	-0.01	-0.68	-0.62
	Sig.	**0.04**	0.99	0.04	0.08
ForceL	Pearson R	0.50	-0.21	-0.39	-0.87
	Sig.	0.17	0.59	0.30	**0.00**
VelocityL	Pearson R	0.62	0.20	-0.65	-0.48
	Sig.	0.07	0.60	0.06	0.19
HeightR	Pearson R	0.34	-0.07	-0.50	-0.31
	Sig.	0.37	0.85	0.17	0.42
PowerR	Pearson R	0.48	-0.08	-0.64	-0.37
	Sig.	0.19	0.84	0.06	0.33
ForceR	Pearson R	0.55	-0.01	-0.78	-0.37
	Sig.	0.12	0.97	**0.01**	0.32
VelocityR	Pearson R	0.39	-0.01	-0.51	-0.33
	Sig.	0.29	0.99	0.16	0.38
HeightLR	Pearson R	0.49	-0.21	-0.50	-0.44
	Sig.	0.18	0.58	0.17	0.24
PowerLR	Pearson R	0.60	-0.17	-0.59	-0.45
	Sig.	0.08	0.66	0.09	0.22
ForceLR	Pearson R	0.63	-0.07	-0.57	-0.13
	Sig.	0.07	0.86	0.11	0.73
VelocityLR	Pearson R	0.52	-0.13	-0.50	-0.43
	Sig.	0.15	0.75	0.17	0.25

The fact that the correlation was determined between certain variables of explosive strength during the CMJ vertical jump performed with a takeoff on one leg and the angle between sacral bone and hip joint, led the authors to the conclusion that during an examination of a greater number of participants, the results of the research would show, with greater significance, that there is a correlation between the explosive strength of the lower extremities and sagittal postural status. In that sense, it is necessary to carry out new studies, which would include the electromiographic method.

CONCLUSION

Through the quantification of the results, one gains precise insight into the explosive strength status of the lower extremities and sagittal postural status of the participants. The achieved results can be used by the participants themselves, who have taken part in the current research, as well as by other patients when achieving the regular sagittal postural status and adequate muscular potential. It means participating in sports activities on a regular basis, and doing some appropriate corrective exercises, created by experts who are educated in the field of corrective gymnastics.

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POVEZANOST EKSPLOZIVNE SNAGE I SAGITALNOG POSTURALNOG STATUSA

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Vertikalni skok je osmišljen u cilju procene eksplozivne snage donjeg (-ih) ekstremiteta i zdravih i povređenih ispitanika. Uređaj "Myotest" (Myotest SA, Sion, Switzerland), poseduje tehnologiju i metodologiju za procenu navedene eksplozivne snage. Uređaj "Spinal Mouse" (Quantum Health and

Wellness Ltd, Wallasay, England) poseduje tehnologiju i metodologiju za procenu posturalnog statusa, tj., ispitivanje kičmenog stuba ispitanika. Ciljevi ovog istraživanja bili su da se utvrde i kvantifikuju varijable eksplozivne snage donjih ekstremiteta i sagitalnog posturalnog statusa ispitanika, da se utvrdi da li postoji značajna razlika između varijabli eksplozivne snage donjih ekstremiteta, da se utvrdi da li postoji značajna razlika između varijabli sagitalnog posturalnog statusa, kao i da se utvrdi da li postoji povezanost varijabli eksplozivne snage donjih ekstremiteta i varijabli sagitalnog posturalnog statusa. Devet ispitanika koji upražnjavaju različite sportske aktivnosti je sačinjavalo uzorak, visine 178,00±11,36 u cm, težine 77,00±13,95 u kg i starosti 22,89±1,62 godina (Mean±St.Dev.). U cilju procene eksplozivne snage, ispitanici su demonstrirali pet vertikalnih skokova (CMJ), koristeći tri različita protokola maksimalnog vertikalnog pomeranja: 1) sa levom odskočnom nogom; 2) sa desnom odskočnom nogom; 3) odskokom sa obe noge. U cilju ispitivanja kičmenog stuba, ispitanici su zauzimali normalan uspravan stav. Rezultati deskriptivne statistike su pokazali, da su najveće vrednosti varijable eksplozivne snage ostvarene primenom protokola (CMJ) odskoka sa obe noge, dok je kod posturalnog statusa primetan veliki broj deformiteta. U odnosu na korelaciju eksplozivne snage i posturalnog statusa, značajna korelacije je utvrđena samo između određenih varijabli eksplozivne snage utvrđenih nakon primene CMJ protokola izvedenih sa jednom odskočnom nogom (levom ili desnom) i određenih varijabli sagitalnog posturalnog statusa. Moderan način života utiče na posturalni status. Kada recimo, smanjenje lumbarne lordoze nije "propraćeno" adekvatnim smanjenjem torakalne kifoze, karlica vrši kompenzaciju, tj., promenu inklinacije. Ukoliko navedena kompenzacija nije dovoljna da bi se održao ravnotežni položaj težišta tela (TT), osobe menjaju ugao u zglobovima kolena. Činjenica da postoji korelacija između određenih varijabli eksplozivne snage i određenih varijabli sagitalnog posturalnog statusa, navode autora na pretpostavku, da bi brojniji uzorak ispitanika mogao da ukaže na značajniju korelaciju. Dobijeni rezultati mogu biti od koristi samim ispitanicima koji su učestvovali u aktuelnom istraživanju, kao i svim ostalim pacijentima u postizanju njihovog cilja, a to je pravilan sagitalni posturalni status i adekvatan mišićni potencijal donjih ekstremiteta, regularnim upražnjavanjem fizičkih aktivnosti, odnosno primenom odgovarajućih korektivnih vežbi, određenih od strane stručnih lica iz oblasti korektivne gimnastike.

Ključne reči: *eksplozivna snaga, vertikalni skok, sagitalni posturalni status, korelacija.*