Original Article

doi: 10.16926/par.2019.07.18

Impact of balance exercises on the elimination of functional muscular disorders in volleyball players

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Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract

Introduction: The research was aimed at obtaining and extending the findings of the functional state of musculoskeletal system of the research sample of volleyball players, and also the possibilities of influencing the balance exercises in the sports training of athletes. *Material and Methods:* The research sample consisted of 12 volleyball players (girls) from the Stara Lubovna Volleyball Club. The first measurement was carried out in September 2015. The average decimal age of the volleyball players was 15.76±0.88 years. In the final measurement, which was made after three months in January 2016 and after the application of a targeted program of balance exercises, the average decimal age of the group was 16.09±0.88 years. *Results:* The initial measurement of the players found a high percentage of functional muscle disorders and the most risky muscles and muscle groups that tend to shorten and weaken in the analyzed subjects. Based on the above, a targeted compensation program of balancing exercises was developed. A significant decrease of the incidence of measured functional muscle disorders to $p<0.01$ of shortened flexors of the knee, musculus rectus femoris, of weakened abductors of hip joint, deep neck flexors, lower fixators of spatulas and broken motor stereotypes - one leg stand and push up was observed after the inclusion of experimental factor into the training plans actively for a three-month period. We noted a decrease in shortened musculus triceps surae, musculus quadratus lumborum a musculus iliopsoas, of weakened abdominal muscles and of sitting down stereotype on the significance level of $p<0.05$. *Conclusion:* Significant conclusions may be drawn from the acquired statistical data: the inclusion of appropriate and regular balance exercises in the training process of young athletes has a positive impact on reducing or eliminating muscle functional disorders of the musculoskeletal system in its individual components - shortened muscles, weakened muscles and impaired movement patterns.

Keywords: balance exercises, functional muscular disorders, impaired movement patterns, shortened muscles, weakened muscles

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Recevied: 25.01.2018; Accepted: 04.02.2019; Published online: 31.07.2019

Cite this article as: Kanasova J, Czakova N, Divinec L, Veis A, Solvesterova M. Impact of balance exercises on the elimination of functional muscular disorders in volleyball players. Physical Activity Review 2019; 7: 152-159. doi: 10.16926/par.2019.07.18

INTRODUCTION

Competitive sports are typical for excessive and one-sided overloading of the musculoskeletal system, which creates a risk of functional muscular disorders and injuries that can lead to an early termination of the sports career. These risks are greatly affected by high training load, which is carried out without adequate compensation.

The knowledge of muscular imbalance, which can be considered the gravest functional muscle disorder that adversely affects the posture, motion stereotypes, muscular coordination, and is important for good protection of the joints, is of utmost importance. Furthermore, it limits the range of motion in the joints, and their uneven and disproportionate load [1]. This increases the likelihood of injury, accelerates fatigue, increases susceptibility to the disorders of peripheral joints and spinal joints and leads to vertebrogenic defects, which we refer to as vertebrogenic syndromes. It also accelerates the development of degenerative changes in the joints. It may even affect the quality of life of the athletes [2].

There are two recognized causes of muscle imbalance. The first is a biomechanical one: unidirectional repeated movements or sustained postures. The second cause is neuromuscular imbalance due to the predisposition of certain muscle groups to be either tight or weak. The muscles from the 'tonic' group are prone to tightness and shortening and the 'phasic' group is prone to weakness [3].

Back pain, shoulder pain, knee pain, etc. have become a recent phenomenon. Inappropriate functional load of the motor system, i.e. insufficient or excessive, or qualitatively inappropriate load, i.e. one-sided, especially in athletes, is the most common cause of pain. The musculoskeletal system is negatively affected by negative emotions, stress and also by the quality of postural behavior. The higher the level of postural behavior, the higher the level of muscle balance [4].

The postural functions, controlled by the subconscious mind, are followed by the free motor programs and movement patterns. The programs to maintain the body position and movement are formed and reinforced over time through learning and repetition and belong to motor learning [5].

In general, until recently the physical preparation in volleyball was devoted exclusively to surface muscles, which is the direct executor of the actual motion. For these muscles to be as efficient as possible, these muscles must be adequately supported in the body of an athlete by the deep stabilization system. The development and strengthening of the muscles in the deep stabilization system leads to a reduction in functional muscle disorders, better activity of the surface muscles and creation of a stronger postural base for the movement, which is necessary both for the athlete's compact motion and his/her individual body parts [6].

To a large extent, the muscles of the deep stabilization system are static, or with only a very few short concentric and eccentric contractions. Therefore, their development is best achieved by equilibrium and balance exercises using both large and small balls and various balancing boards [6]. In sports training [7], it is necessary to focus on the specific needs of the athlete and on various other factors that must be taken into account: type of sport, mobility – stability, muscle shortening, strength predispositions, and other individual factors. Regular balance training results in the activation of all muscles around the joint, a more thorough cooperation of the individual muscles, an overall better coordination of motion, modification of muscular disbalance and improved functioning of the deep stabilization system.

The aim of our research was to determine the effects of balance exercises on functional muscle disorders in volleyball players in terms of muscle shortening, muscle weakening and incorrect movement patterns over a period of three months (12 weeks).

MATERIAL AND METHODS

The research sample consisted of 12 volleyball players (girls) from the Stara Lubovna Volleyball Club who actively played volleyball for 4–5 years on average. The selection of the research sample was intentional. The first measurement was carried out in September 2015. The average decimal age of the volleyball players was 15.76±0.88 years, their average body weight was 59.39±7.75

kg, the players were 169.41±4.83 cm tall on average. In the final measurement, which was made after three months in January 2016 and after the application of a targeted program of balance exercises, the average decimal age of the group was 16.09±0.88 years, it had an average weight of 59.20±7.81 kg, average height of 170±4.46 cm.

We used a single-group gradual experiment. To investigate the functional muscle disorders (muscle imbalance), we used [8] method modified by [9] for the purposes of sports practice. In the testing method, we proceeded according to [10]. To collect the data we used 11 tests for shortened muscles, 5 tests for weakened muscles and 7 tests for movement patterns. The administrators purposely built a motion program with balance exercises with and without equipment (fitballs and overballs), which were focused on shortened muscles (m. rectus femoris, m. pectoralis major, m. levator scapulae, m. trapezius, m. quadratus lumborum, m. triceps surae), weakened muscles (stomach muscles, hip joint extensors, lower shoulder blade fixators) and wrong movement patterns standing on one leg, hip joint extension and pushup.. The affected muscles, muscle groups and movement patterns were evident at least in 50% of the test subjects during the initial examination. When selecting the exercises, we followed the methodology of [11,12]. Balance exercises were adapted to the load and intensity of sports training, and we included them in the extent of 3×15 minutes per week in the final part of sports training.

We used percentage analysis and frequency analysis to qualitatively analyze the functional muscle disorders. The statistical significance of changes in shortened muscles, weakened muscles and incorrect movement patterns at each of these measurements was evaluated with Chi-square (χ^2) at a 1%, 5% and 10% level of significance. The practical and substantive significance was assessed using the Effect Size (Cramer’s Phi – φc and Cohen's – φw), drawing from his estimate: 0.10 – small effect; 0.30 – medium effect; 0.50 – great effect [13].

RESULTS

Functional muscle disorders were noted during the initial measurements in all surveyed subjects. The results of the overall muscle imbalance were influenced by the strictness of the evaluation criteria because the incidence a single shortened muscle, weakened muscle or incorrect movement pattern made us place the subject into the group with an incidence of muscle imbalance. After a three-month exercise program, the occurrence of functional muscle disorders lowered (muscle imbalance, shortened muscles, weakened muscles and incorrect movement patterns) by 16.6% to 25% (table 1).

In assessing the frequency of shortened muscles, we have noted shortened muscles in all measured subjects (table 2). The most frequent shortened muscle was m. rectus femoris (straight muscle of the thigh), which was diagnosed in 66.7% of the subjects. The second most commonly occurring shortened muscle was m. pectoralis major (great pectoral muscle) in 62.5% of the subjects. The third most vulnerable muscle was m. trapesius (upper trapezoid muscle) with 54.2% of the subjects and levator scapulae with the same percentage of occurrence. The fourth most frequently occurring muscle, which had a tendency to be shortened, was m. triceps surae, which was observed in 50% of all subjects. After the application of our intentional experimental procedure, we observed a reduction in the incidence of all shortened muscles and muscle groups from 4.2% to 45.9%. The most significant decrease in the incidence of muscle shortening was found in m. rectus femoris (straight muscle of the thigh) by 45.9% and knee flexors by 33.4%. We observed a significant reduction in these postural muscles at $p<0.01$ and in m. triceps surae by 33.3%, m. quadratus lumborum (quadriceps) by 29.1% and m. iliopsoas (iliopsoas muscle) by 25% at $p<0.05$ (Tab. 2).

In the initial measurements, the results clearly pointed to a group of hip joint extensors and abdominal muscles as the most weakened muscle group, which was diagnosed in 75% of the subjects. Other weakened muscles in volleyball players included lower shoulder blade fixators in 54.2% of the subjects, and deep neck flexors in 41.7% of subjects (Fig. 3). After introducing the targeted program of balance exercises we have reduced the incidence of muscle weakness on average by 30.72% (Fig. 3). The results from the final measurements suggest a reduced incidence of weakened muscles. The largest decrease of 37.5% was observed in lower shoulder blade fixators. These were followed by abdominal muscles and deep neck flexors, which were observed in 33.4% of the test subjects. In these phasal muscles we observed significant reductions at $p < 0.01$, and in abdominal muscles at $p < 0.05$. We have achieved a 25% lower incidence also in hip joint extensors at a significance level of $p < 0.10$ (table 3).

Seating was the most frequently incorrect movement pattern in all subjects at 75% dirong the initial examinations. The second most frequent incorrect movement pattern was standing on one leg, with at least 58.5% of the subjects. When evaluating other movement patterns, i.e. pushups and hip joint extensions, we noticed their incidence in 54.2% and 45.8% of the subjects. In the final measurements, we have observed a reduction in the occurrence of the above movement patterns by an average of 30%. A significant reduction in the incidence, i.e. 41.6%, was observed in standing on one leg and pushups (by 37.8%) and hip joint extensions (by 12.5%). In these movement patterns, we achieved a significant reduction at $p < 0.01$. We recorded the reduction of incidence of seating at a significance level of $p< 0.05$ (Table 4).

The above mentioned significant changes reached by objective and correlation analysis (chi-square) are also supported by the Cramer Phí – φc and Cohen – φw (Effect size) test, which assessed the results as medium or great Effect size, which means that the results were not affected by statistics (table 2-4).

When examining the functional muscle disorders in volleyball players, we have seen differences even in terms of functional laterality with a right-sided predominance. The most significant right-hand predominance was noted in the following shortened muscles: m. pectoralis major (pectoralis muscle), m. rectus femoris (rectus muscle of the thigh) m. upper trapezius, m. levator scapulae and the incorrect movement patterns in standing on one lower limb with right-sided predominance. With the targeted exercise program in place, we observed an improvement by 33% in standing on one lower limb, 25% in m. rectus femoris and 8.3% in m. pectoralis major (table 5).

Table 1. Changes in overall muscle imbalance, shortened muscles, weakened muscles, incorrect movement patterns in volleyball players

Changes in functional muscle disorders in volleyball players				
Functional muscle disorders	Shortened muscles (%)	Functional muscle disorders (%)	Shortened muscles (%)	Functional muscle disorders (%)
Initial measurements	100.0	100.0	100.0	100.0
Final measurements	83.4	83.4	75.0	83.4

Table 2. Changes in the frequency of muscle shortness in volleyball players

Changes in the frequency of muscle shortness in volleyball players						
Shortened muscles	Initial measurements (%)	Final measurements (%)	Chi-square (χ^2)	p-value	Level of significance	Effect size
Upper trapezoid muscle	54.2	25.0	0.284	0.5941	$p < 0.05$	1.486 GE
M.levator scapulae	54.2	25.0	0.284	0.5941	$p < 0.05$	1.486 GE
M.pectoralis major	62.5	45.8	1.343	0.2465		0.709 GE
M.iliopsoas	33.3	8.3	4.547	0.0330	$p < 0.05$	1.562 GE
M.rectus femoris	66.7	20.8	10.243	0.0014	$p < 0.01$	4.829 GE
M.tensor fascia latae	25.0	20.8	0.118	0.7312		0.199 GE
Hip joint abductors	16.7	8.3	0.762	0.3827		0.520 GE
Flexors of the knee	41.7	8.3	7.111	0.0077	$p < 0.01$	2.412 GE
M.quadratus lumborum	45.8	16.7	4.752	0.0293	$p < 0.05$	1.619 GE
M.erector spinae	8.3	0	2.087	0.1486		0.917 GE
M.triceps surae	50.0	16.7	6.000	0.0143	$p < 0.05$	2.000 GE

Level of Effect size: Small effect SE, Medium effect ME, Great effect GE

Table 3. Changes in the frequency of muscle weakness in volleyball players

Changes in weakened muscles and muscle groups						
Weakened muscles	Initial measurements (%)	Final measurements (%)	Chi-square (χ^2)	p	Level of significance	Effect size
Deep neck flexors	41.7	8.3	7.111	0.0077	p < 0.01	2.412 GE
Abdominal muscles	75.0	41.7	5.486	0.0191	p < 0.05	0.877 GE
Lower shoulder blade fixators	54.2	16.7	7.378	0.0066	p < 0.01	1.052 GE
Hip joint extensors	75.0	50.0	3.200	0.0736	p< 0.10	0.644 GE
Hip joint abductors	25.0	0	6.857	0.0088	p < 0.01	2.309 GE

Level of Effect size: Small effect SE, Medium effect ME, Great effect GE

Table 4. Changes in incorrect movement patterns in volleyball players

Changes in movement patterns						
Movement patterns	Initial measurements (%)	Final measurements (%)	Chi-square (χ^2)	p	Level of significance	Effect size
Hip joint extension	45.8	33.0	0.784	0.3759		0.528 GE
Hip joint abduction	25	0	6.857	0.0088	p < 0.01	2.309 GE
Seating	75.0	41.7	5.486	0.0192	p < 0.05	1.835 GE
Pushup	54.2	16.7	7.378	0.0066	p < 0.01	2.526 GE
Arm abduction	25.0	16.7	0.505	0.4773		0.346 ME
Standing on one leg	58.3	16.7	8.889	0.0029	p < 0.01	0.965 GE
Breathing pattern	41.7	25.0	1.500	0.2207		1.558 GE

Level of Effect size: Small effect SE, Medium effect ME, Great effect GE

Table 5. Changes in incorrect movement patterns in volleyball players

Changes in functional muscle disorders in volleyball players					
Functional muscle disorders	m. pectoralis major (%)	upper m. trapezius (%)	m. levator scapulae (%)	m. rectus femoris (%)	Standing on one leg (%)
Initial measurements	33.3	16.7	16.7	33.3	33.3
Final measurements	25.0	16.7	16.7	8.3	0

DISCUSSION

In the introductory testing of functional muscular disorders, we noted the incidence of muscle imbalances (table 1) in each volleyball player. Our results correspond to the research conducted by Majerik [14], who confirmed a 100% incidence of muscle imbalance in students doing performance sports observed 56 students from a sports grammar school, 15 to 18 years old. The incidence of muscular imbalance in young athletes was in the range of 71% to 100%.

Our findings are consistent with the others results who diagnosed a 100% incidence of shortened muscles and weakened muscles in the sample of 10 volleyball players aged 15–18 [15]. The most commonly occurring shortened muscle was m. rectus femoris (straight muscle of the thigh), which was also diagnosed in our research sample as the most frequent one. Our findings correspond to the others results who reported m. rectus femoris (straight muscle of the thigh) as the most frequently occurring shortened muscle in sportsmen [14,15]. Further, our results are consistent with the conclusions of research conducted by researchers who reported a 100% incidence of shortened upper trapezius muscle and pectoralis muscle [16]. The results point to a great overload in the area of the upper cross syndrome in volleyball players. In their research sample, the 42 volleyball players aged 15 to 19 had a high incidence (92%) of shortened knee flexors, m. quadratus lumborum as well as m. rectus femoris (straight muscle of the thigh) and m. levator scapulae. Also, the comparison of the results of various intervention programs on shortened muscles is very interesting. Most authors stress the influence of compensatory exercises, which is demonstrated by their research results [17–20]. Used motion exercises on unsteady surfaces in 24 young athletes with decimal age of 10.59 [21]. After the end of targeted influencing, he noted a significant reduction in the iliopsoas muscle in girls at

$p<0.01$. In boys, he experienced a statistically significant reduction in the incidence of shortening at a 1% level of significance in m. iliopsoas and at a 5% significance level in m. quadratus lumborum. Our results partially coincide with the results of other who noted a significant reduction in the incidence of shortening at $p<0.01$ in iliopsoas muscle and at $p<0.05$ in knee flexors, m. rectus femoris, straight thigh muscle and tensor fasciae latae muscle in 10–11 year old football players [22].

In our initial measurements and analysis of the results of incidence of muscle weakness, we found that the highest incidence was noted in abdominal muscles and hip extensors, which was diagnosed in 75% of the subjects. These results correspond with the conclusions of other research [14–16,23] who state that the extensors of the hip joint and abdominal muscles are the most frequently occurring weakened muscles in athletes. In other study reported a 45% incidence of weakened hip joint extensors in volleyball players, 30% incidence of weakened abdominal muscles and 10% incidence of weakened lower shoulderblade fixators [15]. By comparison, research by Voralek et. al. [16] confirms up to a 100% incidence of weakened abdominal muscles and 93% incidence of lower shoulderblade fixators in the experimental group of 42 professional volleyball players. Our findings partially coincide with the results of Trudic [24], who also used unsteady surfaces to influence the muscle imbalance in 64 girls with an average age of 12.6 years. After a three month long fitball exercise, this author managed to achieve a significant reduction in the incidence of weakening at $p<0.05$) in four out of five investigated muscles and muscle groups – deep neck flexors, abdominal muscles, hip joint extensors and lower shoulderblade fixators.

Our results are supported by the findings of other [17] who found that seating was the most frequent incorrect movement pattern in young tennis players in both sexes. Of the individual types of muscle imbalance, the adjustment of incorrect movement patterns takes the longest time – eventually a whole year. Often, the adjustment of an incorrect movement pattern cannot be achieved [25-28]. In accordance with Malatova et. al. [1], we consider it crucial especially in young athletes to determine the optimal programming of motion, pay attention to the correct implementation of individual simple movements, diagnose incorrect movement patterns and try to rectify them.

We noted the differences with right-sided predominance in volleyball players in the assessment of muscle imbalance in terms of functional laterality. Our findings correspond to the results of manual testing conducted by Voralek et. al. [29], which show that a functional disorder of the dominant upper limb is quite common in volleyball players. In their sample, 8 players out of 10 checked out positive. The results are justified by an increased unilateral load on the spiker arm, which is periodically overloaded due to the player's role (especially in spikers), deployment in league games, and sports performance. In just a few months without adequate load balancing and comprehensive compensation, these factors contribute to the distortion of the musculoskeletal system of the dominant arm.

The results of a gradual single-group experiment point to the possibility of using the balance exercises in sports training of young volleyball players, which can reduce the progression of shortened muscles, weakened muscles and incorrect movement patterns [30,31].

CONCLUSION

In the initial examination, we diagnosed the functional muscle disorders in 12 volleyball players, which included shortened muscles, weakened muscles and incorrect movement patterns. As a result of our experimental procedure, we reduced their occurrence by 16.6% to 25%. The most significant reduction of muscle shortening in the final measurements was observed in the straight muscle of the thigh by 45.9%, in flexors by 33.4% at the $p<0.01$ level of significance and in quadratus lumborum by 29.1% at $p<0.05$. The most frequent weakened muscles were the abdominal muscles and hip joint extensors, especially m. gluteus maximus (big sitting muscle). After introducing the motion program with balance exercises into the training unit, we observed a reduction of incidence of weakening in abdominal muscles by 33% at a $p<0.05$ level of significance and in hip joint extensors at a $p<0.10$ level of significance. In professional performance volleyball, we often note a one-sided overloading of certain muscle groups. Our results point to the possibility of a targeted use of balance exercises in the process of sports training as a suitable complement to the excessive and one-sided physical load, which lowers the incidence of functional muscle disorders in volleyball players. We recommend a continuous monitoring of the muscles and their involvement in the basic movement patterns and intentionally influence them. The balance exercises should be adapted to the load and intensity of sports training.

ACKNOWLEDGMENTS

The paper is based on support of the grant role of MS VVS SR – VEGA No.1/0410/17 entitled "Changes in the level of muscle imbalances, body posture and flexibility in athletes".

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