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Electromyographic Activity of Shoulder Muscles in Sitting volleyball Players During Push-Up and Chest Press with and without TRX

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ABSTRACT

Background:This study aimed to investigate the electromyographic (EMG) activity of selected shoulder girdle muscles in sitting volleyball players during push-up and chest press exercises, performed with and without TRX suspension training. **Methods:** Ten sitting volleyball players who met the inclusion criteria voluntarily participated in the study. EMG signals were recorded using an 80-channel USB+2 device (frequency: 1000 Hz) and bipolar surface electrodes. The muscles analyzed included the triceps brachii, biceps brachii, and deltoid on both the right and left sides. Signal processing was conducted using OT Biolab software, employing a band-pass filter of 10–350 Hz, and the root mean square (RMS) of the signals was extracted. The maximum voluntary isometric contraction (MVIC) method was used to normalize the EMG signals. Data were analyzed using SPSS software version 22. Statistical tests included the dependent t-test and repeated measures ANOVA to compare the four experimental conditions.

Results: The normalized EMG activity of the right and left triceps and deltoid muscles, as well as the right biceps brachii, was significantly higher during TRX push-ups compared to traditional push-ups ($p < 0.05$). Similarly, during the chest press with TRX, the normalized EMG activity of the right ($p = 0.02$) and left ($p = 0.002$) deltoid muscles and the left biceps brachii ($p = 0.025$) was significantly greater than the chest press using dumbbells. A significant interaction was observed between the TRX and exercise factors ($F = 5.34$, $p = 0.046$, $\eta^2 = 0.37$). Additionally, a significant three-way interaction was found among muscle, TRX, and exercise factors ($F = 6.31$, $p = 0.02$, $\eta^2 = 0.61$). **Conclusions:** TRX exercises elicited significantly higher muscle activation compared to traditional exercises. Furthermore, TRX push-ups promoted more symmetrical muscle activity than traditional push-ups. These findings suggest that TRX exercises are an effective and low-risk alternative for inclusion in training programs for sitting volleyball players.

KEYWORDS

sitting volleyball, push up, chest press, EMG, TRX

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Introduction

Sitting volleyball is a highly demanding Paralympic sport that requires exceptional upper body strength, agility, and coordination. Players rely entirely on their upper limbs and hands to move across the court and perform techniques such as passing, attacking, defending, and serving. According to the rules of the game, players must maintain contact with the floor with at least one part of their hips during these actions, which places significant physical demands on their shoulder girdle muscles [1, 2]. These muscles are subjected to considerable stress during both training and competition, making their strength and endurance critical for optimal performance [3-5].

For sitting volleyball players, who often have limited or no lower limb functionality, the development of upper extremity strength is not just beneficial but essential. Strong upper limbs enable players to move quickly, maintain balance, and execute powerful movements, all of which are crucial for effective gameplay [2]. While it is true that sitting volleyball players typically possess strong upper bodies due to the nature of their sport, this does not negate the need for targeted training programs. In fact, the repetitive and intense use of the shoulder girdle in sitting volleyball can lead to muscle imbalances and overuse injuries if not properly managed [6]. Research has consistently shown that enhancing the strength of the shoulder girdle not only improves athletic performance but also reduces the risk of injuries and increases motivation among athletes [7].

Resistance training is a well-established method for building muscle strength [8], and in recent years, suspended training systems like TRX have gained popularity as an innovative and effective approach. TRX utilizes the athlete's body weight and gravitational force to create resistance, offering a versatile and portable solution for improving physical fitness [9]. The TRX system involves performing exercises while suspended from straps, which allows for a wide range of movements that engage multiple muscle groups simultaneously [10]. Among its many benefits are improved overall physical fitness, increased fat burning, enhanced proprioception, better balance, and stronger core muscles [11-13]. Recent studies have highlighted that closed-chain, multi-joint, and full-body exercises, such as those performed with TRX, are more effective for improving core stability compared to isolated core exercises [14]. For example, exercises like the plank have been shown to enhance the body's ability to transfer force through the core region, which is particularly important for athletes who rely heavily on their upper bodies [15]. Suspended exercises also provide unique conditions for challenging core stability and engaging multiple muscle groups, making them an excellent choice for athletes seeking to improve their functional strength [16].

One of the key advantages of TRX is its ability to create an unstable environment, which activates more muscles and increases exercise intensity, leading to greater gains in strength and endurance [17]. Despite these benefits, TRX training remains underutilized in many sports, including sitting volleyball, where traditional training methods still dominate [18]. This is surprising, given that TRX has been shown to improve core muscle strength and enhance muscle contractibility, which are critical for athletes who rely on their upper bodies for performance [19, 20]. For sitting volleyball players, who face unique physical challenges due to their disabilities, finding effective and accessible training methods is of paramount importance. TRX exercises, with their simplicity and portability, offer a promising solution. However, the impact of TRX on muscle activity in sitting volleyball players, particularly in comparison to traditional resistance training, has not been thoroughly investigated.

One might question why TRX exercises are necessary for sitting volleyball players, given their already strong upper bodies. The answer lies in the specific demands of the sport and the need for balanced muscle development. While sitting volleyball players do possess significant upper body strength, this strength is often concentrated in certain muscle groups, such as the pectoralis major and anterior deltoid, due to the repetitive nature of their movements. This can lead to imbalances between agonist and antagonist muscles, increasing the risk of injury and limiting performance potential [21]. TRX exercises, with their emphasis on full-body engagement and core stability, can help address these imbalances by activating underutilized muscles and promoting more symmetrical strength development [22]. Moreover, the unstable nature of TRX exercises challenges the neuromuscular system in ways that traditional resistance training cannot. This instability forces athletes to engage stabilizing muscles, improving proprioception and coordination, which are critical for the dynamic and unpredictable movements required in sitting volleyball [23]. Additionally, TRX exercises can be easily modified to suit the individual needs and abilities of athletes with disabilities, making them an inclusive and adaptable training option [24].

Studies on healthy individuals have shown that TRX exercises, such as push-ups, increase the activation of the pectoralis major, triceps brachii, and anterior deltoid muscles compared to traditional methods [25-27]. These findings suggest that TRX may be particularly effective for targeting the muscles of the shoulder girdle, which are crucial for sitting volleyball players. However, the results are not entirely consistent. For instance, Zibaii et al. (2016) reported no significant difference in anterior deltoid activation between bench press exercises performed with a barbell and TRX, but noted reduced pectoralis major activation and increased trapezius activation with TRX [28]. Similarly, another study found no significant difference in core muscle activity during plank exercises with and without upper limb support [29]. These inconsistencies highlight the need for further research to better understand the effects of TRX on muscle activation, particularly in populations with unique physical demands, such as sitting volleyball players.

Given the lack of research on muscle activity in sitting volleyball players during TRX exercises, and the conflicting results from studies on healthy individuals, there is a clear gap in the literature that needs to be addressed. This study aims to compare the muscle activity of the shoulder girdle during TRX training with traditional resistance training methods in sitting volleyball players. By doing so, it seeks to identify the most effective training approach for enhancing athletic performance in this population. The findings of this study could have significant implications for the development of training programs for sitting volleyball players, potentially leading to improved performance, reduced injury risk, and greater overall well-being for athletes with disabilities.

Material and Methods

Participants

The statistical population of this research consisted of all male sitting volleyball players in the city of Tabriz. Out of these individuals, 10 sitting volleyball players who met the requirements of the research, voluntarily participated as the statistical sample in this study (Table 1). Based on the G*power software, with the effect size of 0.50, α of 0.05, and power of 0.95, 10 subjects were sufficient for this study.

Table 1: Anthropometric characteristics of subjects

age (years)	weight (kg)	height (cm)
35.63 ± 5.74	75.69 ± 5.39	174.96 ± 3.96

The inclusion criteria for the participants include having a regular sports history of more than 10 years in the field of sitting volleyball, no history of musculoskeletal disorders in the upper limbs, no fractures or dislocations in the shoulder, no history of shoulder pain, and no shoulder deformities. In addition, the individuals with unilateral lower limb disability were specifically those who had lower limb disability in their right foot and were capable of performing the desired exercises. The subjects were excluded if they had cardiovascular diseases, neuromuscular disorders, bilateral or left-sided lower limb disability, and high blood pressure. Prior to the commencement of this study, personal information, medical history, and sports background of the participants were obtained from their sport medicine documents. As well as, necessary information regarding the research procedures and guidelines that participants needed to follow, were provided to them both in written and verbal form. Then written informed consent forms were obtained from the participants, indicating their voluntary willingness to participate in the research.

Experimental design

An 80-channel electromyography device of USB+2 model, made in Italy (with a sampling frequency of 1000 Hz), and bipolar surface electrodes were used for recording muscle activity. The electrodes were placed on the triceps brachii, biceps brachii, and anterior deltoid muscles on both the right and left sides of the body, according to the European SENIAM protocol [30, 31]. Before placing the electrodes on the participants' skin, all hair in that area was trimmed, and to minimize skin surface resistance, the skin was gently cleaned and wiped with medical alcohol [32].

The protocol for conducting the tests was as follows: after placing the electrodes in the appropriate locations, the maximum voluntary isometric contraction (MVIC) tests were performed separately for each muscle [33, 34]. Then, electromyographic activity of the muscles was recorded during the following activities: a) Swedish push up, b) push up with TRX, c) bench press with a halter, d) bench press with TRX. Each movement was repeated three times. Then the signals were processed using OT Biolab software and filtered using a band-pass filter of 10 Hz to 350 Hz. Also, a 50 Hz notch filter was used to eliminate the noise caused by the city's electrical power. For the analysis of muscle activity, the root mean square (RMS) analysis method was used and the maximum RMS was recorded. Then the average intensity of muscle activity in three repetitions was considered for subsequent analyses. Then, to normalize the obtained data, the RMS of muscle activity during each movement was divided by the RMS obtained during the execution of the MVIC of the same muscle, and the intensity of muscle activity was expressed as a percentage of MVIC. In this technique, the individual contracts the target muscle to its maximum capacity in a specific position without any joint movement [35].

Statistical analysis

For statistical analysis, version 22 of the SPSS software was used. The normality of the data was examined using the Shapiro-Wilk test, and the results indicated that the data follows a normal distribution. Therefore, parametric tests were used for data analysis. Repeated measures ANOVA (to evaluate the difference between the 4 experimental conditions) was used for statistical analysis. Additionally, a post-hoc Bonferroni test was employed at a confidence level of 95%.

RESULTS

Table 2 shows the results of normalized electrical activity of shoulder girdle muscles during push up with and without TRX in sitting volleyball players. According to this table, it can be observed that in these players, the activity of the right and left triceps muscle, the right biceps brachii, and the right and left deltoid muscles during push up with TRX was significantly higher than normal push up ($p<0.05$). However, no significant difference was observed in the left biceps brachii muscle during the push up with and without TRX ($p>0.05$).

Table 2: Mean and standard deviation of normalized muscle activity of the deltoid, biceps brachii, and triceps brachii on the right and left sides during push up and chest press with and without TRX in sitting volleyball players

	Muscles	Side	Push-up	With TRX	p Value
push up	Deltoid	right	44.7 ± 9.69	71.82 ± 15.94	0.001
		left	55.59 ± 19.15	64.17 ± 16.85	0.05
	Biceps	right	48.01 ± 10.34	74.06 ± 20.86	0.005
		left	67.96 ± 17.39	67.76 ± 12.97	0.554
	Triceps brachii	right	77.76 ± 22.01	66.33 ± 21.76	0.007
		left	94.48 ± 18.36	88.22 ± 17.45	0.0001
chest press	Deltoid	right	55.58 ± 25.66	68.74 ± 24.06	0.020
		left	40.61 ± 31.77	68.46 ± 26.71	0.002
	Biceps	right	38.68 ± 17.33	39.06 ± 23.18	0.296
		left	39.15 ± 20.05	53.03 ± 23.95	0.025
	Triceps brachii	right	54.86 ± 27.05	53.58 ± 13.30	0.884
		left	50.02 ± 24.81	45.22 ± 9.68	0.474

When performing the chest press exercise with and without TRX, it was found that in sitting volleyball players, performing chest press with TRX increased the intensity of the normalized EMG activity of the right (p=0.02) and left (p=0.002) deltoid muscles, as well as the left bicep brachii (p=0.025). However, no significant differences were observed in the normalized EMG of other muscles during chest press with and without TRX (05/0<p). These results are shown in Table 2.
Furthermore, factor analysis results showed that in overall, without considering the effect of other factors, the intensity of muscle activity was significantly higher when performing the exercise with TRX (F=215.41, p=0.0001, η2=0.96) (Figure 1).

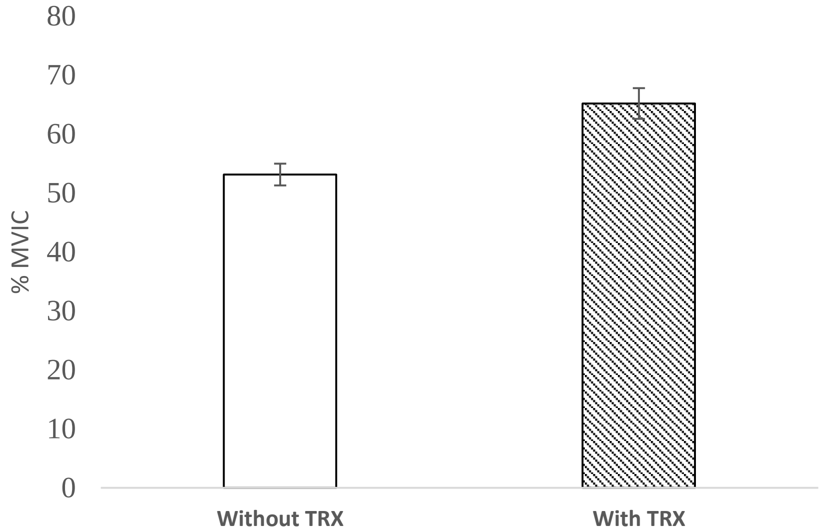

Figure 1: overall normalized EMG activity in exercises with and without TRX

The effect of TRX on the normalized muscle activity during the performing of push up was found to be greater than chest press in sitting volleyball players, and a significant interaction was observed between TRX and exercise factors ($F=5.34$, $p=0.046$, $\eta2=0.37$). This result is illustrated in Figure 2.

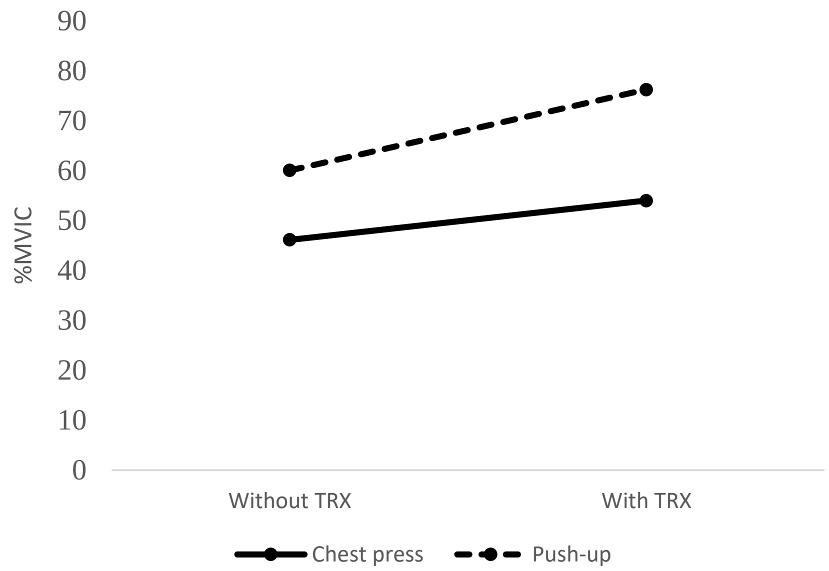

Figure 2: Interaction between two TRX and exercise factors

The pattern of changes in the normalized EMG activity during the execution of chest press and push-up exercises, with and without TRX, was found to be different. A significant interaction effect was observed between three factors of muscle, TRX, and exercise ($F=6.31$, $p=0.02$, $\eta2=0.61$) (see Figure 3).

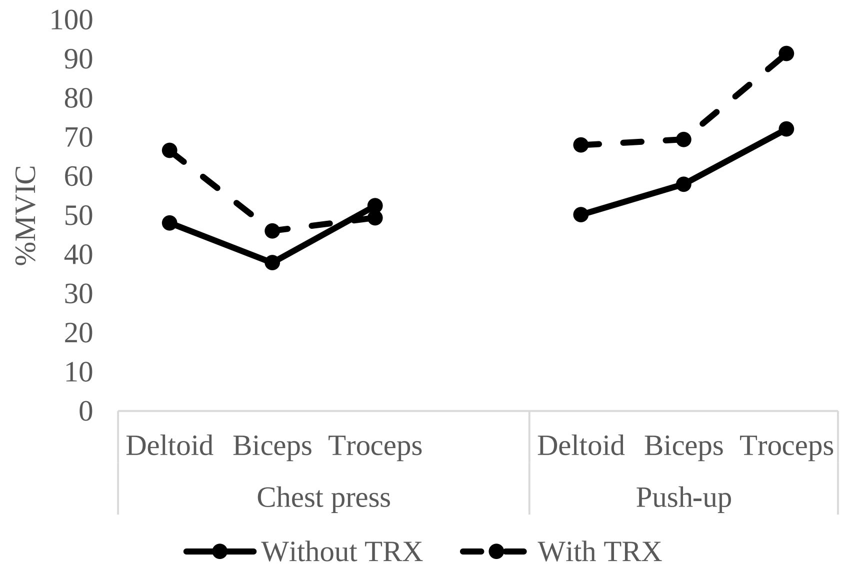

Figure 3: Interaction between the three factors of muscle, TRX and training

In sitting volleyball players, the above-mentioned pattern was different on the right and left sides, and as can be seen in figure 4, the interaction between the four factors of body side, muscle, TRX and training was also significant (F=47.86, p=0.0001, ɳ2=0.92). So, in the traditional push-up, the right triceps muscle was more active than the left side in sitting volleyball players. Still, when performing this movement with TRX, there is not any difference between the normalized EMG activity of the right and left triceps muscles.

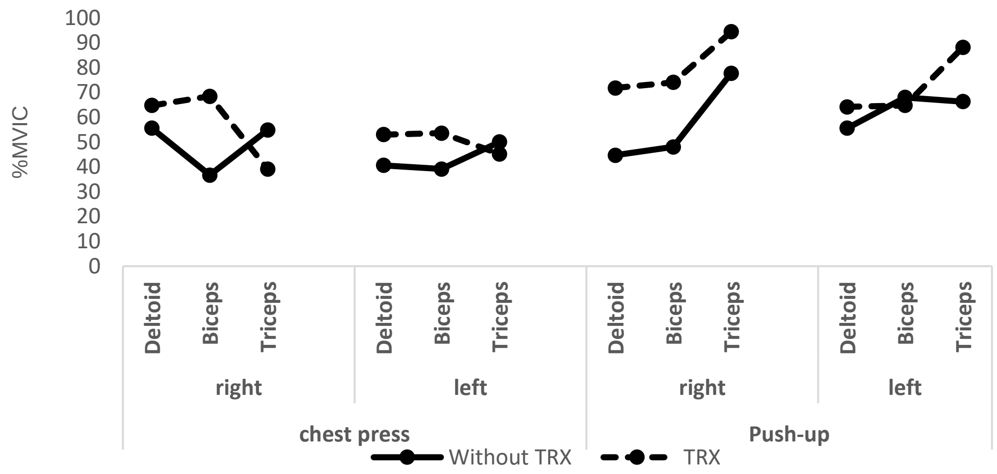

Figure 4: Interaction between four factors of muscle, TRX, exercise and side of the body

Discussion

The aim of this study was to investigate the electromyographic (EMG) activity of the shoulder girdle muscles in sitting volleyball players during the performance of push-up and bench press exercises with and without TRX. The results demonstrated that, overall and without considering the effects of other factors, the intensity of muscle activity was significantly higher during exercises with TRX compared to traditional exercises. Specifically, performing push-ups with TRX led to a significant increase in the intensity of muscle activity in the right and left triceps brachii muscles, the right biceps brachii muscle, as well as the anterior deltoid muscles on both the right and left sides, compared to traditional push-ups [36]. Similarly, during the chest press with TRX, the intensity of muscle activity in the right and left anterior deltoid muscles and the left biceps brachii muscle increased compared to the chest press performed with a barbell [37].

Studies on muscle activity in sitting volleyball players are very limited, making it difficult to compare the results of this study with previous findings. However, the findings of the present study are supported by Polat E.A. and N. A. Guzel (2023), who concluded that there is a significant difference in muscle activation between suspension-based exercises and traditional exercises [36]. They showed that while suspension exercises generally lead to increased activation in most muscle groups compared to traditional exercises, no significant difference is observed in the activation of certain specific muscles [36]. Similarly, Zibaii et al. (2016) found that the intensity of muscle activity during the chest press exercise with TRX was higher compared to the chest press exercise with a barbell at a highly inclined position [37]. In line with this, Hossein Topchu and colleagues (2023) compared the intensity of shoulder girdle muscle activation during push-ups on stable and unstable bases of support and concluded that an unstable base of support (TRX) leads to increased muscle activity [38]. Additionally, the results of Esnar and Esco (2013) and Borreani et al. (2015) support these findings [28, 39]. In another study, Kallatayud et al. (2014) showed that suspended push-ups with a pulley system led to increased activity in the triceps, upper trapezius, rectus femoris, and lumbar muscles, while stable positions caused increased activity of the pectoralis major and anterior deltoid muscles [7]. However, contrary to the findings of the present study, Carbonier et al. (2012) did not report any differences between the hang clean exercise and the squat jump with and without TRX [41]. The discrepancy between these results may be attributed to differences in the type of movement examined, the muscles studied, and the participants involved [41].

During regular push-ups, each active joint has only one degree of functional freedom (i.e., one vertical, up-and-down motion). However, in TRX exercises, the base of support decreases because the individual is suspended. This unstable kinetic chain leads to greater degrees of freedom as the muscles work to prevent unnecessary horizontal and diagonal movements. This creates a "multiple-role" for the active muscles, as they not only act as agonists but also as joint stabilizers [41-43]. As a result, a larger number of muscle fibers are recruited, leading to increased EMG output of the muscles [44-47]. In this regard, Citrakhan and colleagues (2011) and Behm and colleagues (1995) have also shown that during the dumbbell bench press compared to the barbell bench press (which requires more control and stability), changing the degree of freedom from one degree to multiple degrees increases the electrical activity of the muscles during the dumbbell bench press [48, 49].

Furthermore, the results indicated that in sitting volleyball players, the pattern of muscle activity differed between the right and left sides, and there was a significant interaction between the four factors: body side, muscle, TRX, and exercise. In traditional push-ups, the right triceps muscle showed more activity than the left triceps in sitting volleyball players. However, when performing this movement with TRX, there was no difference in the intensity of right and left triceps muscle activity. This result is reported for the first time, so no direct comparison with previous studies is available. However, in line with the findings of the present study, Yazdani and Elhami found asymmetric muscle activity on the right and left sides of the body during walking in individuals with hemiplegic cerebral palsy [50]. They also reported greater muscle activity on the left side for individuals with left hemiplegia [50]. The increased activity of the right triceps muscle compared to the left triceps during push-ups in sitting volleyball players can be explained by the fact that the players in this study had a problem with their right foot. Due to weakness and possibly an inability to bear weight on the right lower limb during push-ups, the body weight was borne more by the right upper limb. To maintain trunk stability and perform the movement, the right shoulder girdle muscles were under greater pressure. Therefore, these individuals likely activated more motor units on their right upper limb compared to the healthy (left) side when performing push-ups. This phenomenon is demonstrated by the observed increase in EMG activity in the muscles of the right upper limb compared to the unaffected left side. However, when performing push-ups with TRX, where the legs are suspended on TRX loops and the body weight is supported by both arms, the weight distribution on both arms becomes similar, leading to similar muscle activation on both the right and left sides.

Based on these findings, it can be concluded that due to the increased muscle activity and symmetric muscle activation in the upper limb muscles of sitting volleyball players during push-ups with TRX, performing this type of exercise is recommended as a suitable and less risky alternative method for sitting volleyball players.

Conclusion

The findings of this study demonstrate that performing push-up exercises with TRX significantly increases muscle activity in the right and left triceps brachii muscles, as well as the right and left deltoids, compared to traditional push-up exercises. Additionally, during bench press exercises with TRX, muscle activity intensity was higher in the right and left deltoids and the left triceps brachii. Factor analysis further revealed that, overall, TRX exercises elicited significantly higher muscular activity compared to traditional exercises. Importantly, push-ups performed with TRX resulted in more symmetric muscle activation patterns than traditional push-ups. These results have practical implications for training programs designed for sitting volleyball players. Given that TRX exercises enhance muscle activity and promote symmetric muscle activation in the upper limbs, they can be effectively incorporated into training regimens to improve performance and reduce the risk of muscle imbalances. Specifically, TRX push-ups and bench press exercises can be used to target key muscle groups, such as the triceps brachii and deltoids, which are critical for movements like passing, attacking, and serving in sitting volleyball. Moreover, the increased muscle activation and symmetry observed with TRX exercises suggest that they may help prevent overuse injuries by ensuring balanced muscle development. This is particularly important for sitting volleyball players, who rely heavily on their upper limbs and are prone to

shoulder and arm injuries due to repetitive motions. Therefore, TRX exercises are strongly recommended as a safe and effective alternative to traditional training methods for this population.
In conclusion, incorporating TRX-based exercises into the training programs of sitting volleyball players can lead to improved muscle activation, enhanced performance, and reduced injury risk. Coaches and trainers should consider integrating TRX exercises into their routines to optimize the physical conditioning of athletes and support their long-term athletic development.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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«مقاله پژوهشی»

فعالیت الکترومیوگرافیک عضلات شانه در والیبالیست های نشسته در حین پوش آپ و پرس قفسه سینه با و بدونTRX

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چکیده

هدف: این مطالعه با هدف بررسی فعالیت الکترومایوگرافی (EMG)عضلات منتخب کمربند شانه‌ای در بازیکنان والیبال نشسته در حین اجرای تمرینات شنا و پرس سینه، با و بدون استفاده از سیستم تعلیقی TRX انجام شد. ده بازیکن والیبال نشسته که معیارهای ورود به مطالعه را داشتند، به‌صورت داوطلبانه در این پژوهش شرکت کردند.

روش شناسی: سیگنال‌های EMG با استفاده از دستگاه USB+2 با ۸۰ کانال (فرکانس: ۱۰۰۰ هرتز) و الکترودهای سطحی دو قطبی ثبت شد. عضلات مورد بررسی شامل سه‌سر بازویی، دوسر بازویی، و دلتوئید در هر دو سمت راست و چپ بدن بودند.پردازش سیگنال‌ها با استفاده از نرم‌افزار OT Biolab و فیلتر میان‌گذر ۱۰ تا ۳۵۰ هرتز انجام شد و مقدار) RMSمقدار میانگین مربعات) سیگنال‌ها استخراج گردید. برای نرمال‌سازی سیگنال‌های EMG، از روش حداکثر انقباض ایزومتریک ارادی (MVIC)استفاده شد. داده‌ها با استفاده از نرم‌افزار SPSS نسخه ۲۲ مورد تجزیه‌وتحلیل قرار گرفتند. آزمون‌های آماری شامل آزمون t وابسته و تحلیل واریانس با اندازه‌گیری‌های مکرر (ANOVA)برای مقایسه چهار شرایط آزمایشی مورد استفاده قرار گرفت.

نتایج: نتایج نشان داد که فعالیت نرمال‌شده EMG در عضلات سه‌سر و دلتوئید راست و چپ و همچنین عضله دوسر بازویی راست، هنگام اجرای شنا با TRX به‌طور معناداری بیشتر از شنا سنتی بود $(p < 0.05)$. همچنین، در تمرین پرس سینه باTRX ، فعالیت نرمال‌شده EMG در عضله دلتوئید راست $(p = 0.02)$ و چپ $(p = 0.002)$و همچنین عضله دوسر بازویی چپ $(p = 0.025)$ به‌طور معناداری بیشتر از تمرین پرس سینه با دمبل بود. یک تعامل معنادار بین عوامل TRX و نوع تمرین مشاهده شد $(F = 5.34, p = 0.046, \eta^2 = 0.37)$.علاوه بر این، یک تعامل سه‌جانبه معنادار بین عضله، TRX، و نوع تمرین وجود داشت $(F = 6.31, p = 0.02, \eta^2 = 0.61)$.

نتیجه گیری: تمرینات TRX در مقایسه با تمرینات سنتی، موجب افزایش قابل‌توجهی در فعالیت عضلانی شدند. همچنین، شنا با TRX نسبت به شنا سنتی، فعالیت عضلانی متقارن‌تری را ایجاد کرد. این یافته‌ها نشان می‌دهند که تمرینات TRX می‌توانند به‌عنوان یک روش مؤثر و کم‌خطر در برنامه‌های تمرینی بازیکنان والیبال نشسته مورد استفاده قرار گیرند.

واژه‌های کلیدی

والیبال نشسته، شنا، پرس سینه، الکترومایوگرافی، TRX

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