The squat exercise recruits core muscles as much as localized exercises

O exercício de agachamento recruta músculos do tronco tanto quanto exercícios localizados

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Abstract

Introduction: In the context of resistance training, which encompasses both strengthening and rehabilitation, the incorporation of global range exercises demands intense activation of the trunk muscle groups, which play a primary role in body stabilization. The squat, notorious for its complexity and effectiveness in activating stabilizers during execution, raises a central question: whether this exercise recruits the muscles more significantly compared to localized exercises, such as push-ups and trunk extensions. **Objective:** To identify the degree of activation of the trunk muscles during squats and compare it with localized exercises for the trunk muscles: lumbar and abdominal. **Methods:** Using surface electromyography, the activation of the iliocostalis, multifidus, internal oblique, external oblique and rectus abdominis muscles was evaluated. The sample included 16 physically active volunteers of both sexes. A repeated measures t-test ($\alpha < 0.05$) was used as an analysis method. **Results:** The iliocostalis, multifidus and internal oblique muscles showed similar levels of activation both in the squat and in their respective isolated exercises, while the rectus abdominis and external oblique muscles showed greater activity during trunk flexion. **Conclusion:** It is possible to infer that squats are an effective exercise for training the iliocostalis, multifidus and internal oblique muscles, while localized exercises are more suitable for strengthening the external oblique and rectus abdominis muscles. Such conclusion can contribute to optimizing the planning of exercise sessions by replacing isolated trunk exercises with squats.

Keywords: Abdominal. Electromyography. Lumbar spine.

Resumo

Introdução: *No contexto do treinamento resistido, que engloba tanto o fortalecimento quanto a reabilitação, a incorporação de exercícios de alcance global demanda uma intensa ativação dos grupos musculares do tronco, os quais desempenham um papel primordial na estabilização corporal. O agachamento, notório por sua complexidade e eficácia na ativação dos estabilizadores durante a execução, suscita uma questão central: se o agachamento recruta de forma mais acentuada a musculatura do tronco comparativamente a exercícios localizados, tais como flexões e extensões do tronco.* ***Objetivo:*** *Identificar o grau de ativação dos músculos do tronco durante o agachamento e confrontá-lo com exercícios localizados para a musculatura do tronco: lombar e abdominal.* ***Métodos:*** *Através da aplicação da eletromiografia de superfície, avaliou-se a ativação dos músculos iliocostal, multífido, oblíquo interno, oblíquo externo e reto abdominal. A amostra englobou 16 voluntários de ambos os gêneros, fisicamente ativos. Empregou-se um teste t de medidas repetidas (α < 0,05) como método de análise.* ***Resultados:*** *Os músculos iliocostal, multífido e oblíquo interno manifestaram níveis semelhantes de ativação tanto no agachamento quanto em seus respectivos exercícios isolados, enquanto os músculos reto abdominal e oblíquo externo apresentaram maior atividade durante a flexão do tronco.* ***Conclusão:*** *É possível inferir que o agachamento se configura como um exercício eficaz para o treinamento do iliocostal, multífido e oblíquo interno, enquanto os exercícios localizados se revelam mais indicados para o fortalecimento do oblíquo externo e dos músculos reto abdominais. Tais conclusões podem contribuir para a otimização do planejamento de sessões de exercícios, mediante a substituição de exercícios isolados de tronco pelo agachamento.*

Palavras-chave: *Abdominal. Eletromiografia. Vértebras lombares.*

Introduction

The squat is widely recognized for its complexity of execution and the high demand for body control that it demands during its performance.[1] Furthermore, it is considered a highly effective exercise for developing strength in the lower limbs.[2] This exercise is classified as global, since it engages muscles of both the lower limbs and trunk in its performance. The versatility of the squat is evidenced by its various versions, which are widely practiced in gyms.[3] Its study extends to its application on unstable surfaces,[4] as well as the use of accessories such as the safety bar[5] and the guide bar,[6] to understand the impact of different approaches on the neuromuscular system. Furthermore, squats are an attractive option due to their ability to simultaneously recruit muscles in the lower limbs and trunk, which optimizes training time. It is plausible that squats can meet the need for training the muscles that are normally the target of isolated trunk exercises. However, there remains a need to thoroughly investigate the dynamics of the trunk muscles during squats.

The use of different bars for its execution, such as the safety bar and the traditional straight bar, do not cause important changes in lower limb and trunk muscle activation.[5] The use of unstable surfaces (such as the bosu ball or balance discs) during squatting, to increase instability, may not affect the recruitment of the stabilizing muscles of the trunk or lower limbs.[7,8] During the squat on the Smith Machine, with knees flexed at 70° or 90°, the lower limb muscles show the same recruitment.[4] In addition to the recruitment of lower limb and trunk muscles being the object of study during squats, specific exercises for the trunk region have also been studied. Rita et al.[9] reported that conventional sit-ups or those using equipment did not show differences in the electromyographic activities of the rectus abdominis and external oblique muscles. According to Martins et al.,[8] there is even an interaction between posture and the recruitment of trunk muscles during abdominal exercises, where changing the positioning of the pelvis is capable of altering the recruitment of muscles such as the iliacus and internal oblique muscles.

In view of the questions outlined above, concern emerges in the literature regarding the relationship between the recruitment of postural muscles in the context of squats and exercises aimed at the trunk muscles. Accordingly, the undertaking of investigations aimed at a detailed understanding of the muscle recruitment inherent both to the execution of squats and to the performance of exercises targeting the same trunk muscles becomes notable and relevant. Such studies aim to fill a gap in understanding by offering scientific insight into evidence-based recommendations regarding exercise choice. In light of this justification, the objective of our study was to compare the levels of trunk muscle activity in performing the squat exercise and in isolated trunk flexion and extension exercises.

Methods

A group of 16 volunteers participated in this study; they were between 18 and 32 years old and characterized as being active in resistance training, performing sessions at least twice a week. This research protocol was approved by the Ethics Committee of the University of Caxias do Sul (CAAE 47719221.6.0000.5341). There was no surgical history on the participants' lower limbs or spine. The analysis of electromyographic activity covered specific muscles, namely: internal oblique (IO), external oblique (EO), rectus abdominis (RA), multifidus (MU) and iliocostalis (IC). The positioning of the electrodes, in bipolar configuration, and the skin preparation procedures adhered to the guidelines proposed by SENIAM.[10] Regarding the abdominal muscles, the study by Queiroz et al.[11] was used as reference for the appropriate placement of electrodes.

To conduct the data collection procedure, initially, a brief warm-up of a general nature was carried out. Subsequently, participants were instructed to perform squats, trunk flexion and trunk extension exercises without load, aiming to familiarize themselves with the movements and specifically prepare the muscles in question. Once this phase was completed, the load to be adopted to perform the squat exercise by each volunteer was determined, using as a parameter the load that would allow the precise performance of 10 repetition maximums (10 RM). It was found that the interruption point occurred when the volunteer showed notable changes in pelvic, lumbar or thoracic positioning during the exercise, or when it was no longer possible to perform repetitions. During the entire process of determining the load, two evaluators positioned themselves next to the volunteer, providing verbal incentives and monitoring the execution of repetitions, in line with the aim of ensuring the safety of the procedure.

Subsequent to the previous step, the maximal voluntary isometric contractions (MVC) of the muscles of interest were assessed. The guidelines for this assessment were based on the recommendations proposed by SENIAM[10] and the guidance of Queiroz et al.[11]

The sequence of procedures was established by performing, in random order, the squat, trunk flexion and trunk extension exercises. The trunk flexion exercise was carried out with the individual lying on a stretcher, with knees flexed, with washers on the hands that were in full extension in front and on the chest. In this context, a load corresponding to 50% of the value used in the squat exercise was used. In turn, the lumbar extension exercise was implemented with the individual in the prone position on the stretcher, allowing the trunk to protrude outside the stretcher. To support this position, one of the extremities of the body remained fixed to the stretcher with the help of one of the evaluators.

During the execution of the squat and trunk extension exercise, a reflective marker was placed on the C7 vertebra, while in the trunk flexion exercise, the marker was placed on the washer. The role of this marker was to enable the determination of repetitions, marking the beginning and end of each movement. Accordingly, data collection pertaining to its three-dimensional position was carried out using the VICON kinemetry system (USA). Regarding synchronization, the electromyographic signal was captured simultaneously with kinemetry using the Telemyo 2400R G2 system (Noraxon, USA), at a sampling rate of 1500 Hz. To delineate the phases of the movement, they used vertical position peaks together with the highest and lowest points. The protocol included performing 10 repetitions for each exercise, with only 8 repetitions being submitted to analysis, excluding the first and last repetitions.

For the analysis of electromyographic data, the Ideal (5 to 500 Hz) and Butterworth (20 to 450 Hz, 4th order) bandpass filters were applied to all electromyographic signals (exercise and MVC); then the root mean square (RMS) value of each of the repetitions was determined. RMS was normalized by MVC. MVC was processed with a 1-second window, where the MVC activation peak was computed. Signal normalization was done on the basis of MVC values. The repeated measures t-test was performed using $\alpha \leq 0.05$. The software used for analysis was SPSS 17.0.

Results and discussion

The results obtained during data collection are expressed in Figure 1. Significant differences between muscle activation in the squat exercise and in isolated exercises were observed in the RA and IO. The other muscles showed a small variation in activation when compared to localized exercises, but with no significant differences.

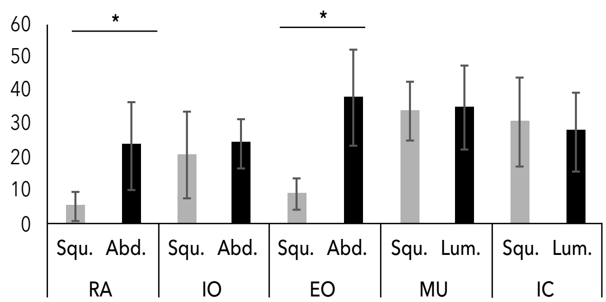

Figure 1 - Bar graph of electromyographic activity results, during squat exercises (gray columns) and during specific trunk flexion and trunk extension exercises (black columns).

Note: Squ = squat; Abd = abdominal exercise (trunk flexion); Lum = lumbar exercise (trunk extension); RA = rectus abdominis; IO = internal oblique; EO = external oblique; MU = multifidus; IC = iliocostalis.

The squat is distinguished as a highly complex exercise, requiring proficiency in body control for precise and appropriate execution. This complexity arises from the need for precise recruitment of muscles aimed at stabilizing the trunk movement.[9,12] Accordingly, the purpose of our study was to elucidate the degree of activation of the trunk muscles during the performance of the squat exercise, in addition to carry out a comparative analysis of this activation in relation to isolated exercises aimed at this muscle region.

IO activation was 20.4 ± 13% (mean ± standard deviation) of MVC during squats and 23.8 ± 7.4% of MVC during trunk flexion, which showed relative effectiveness of squat exercise to recruit the IO, where its activation is essential for increasing the stability of the lumbar spine.[12] The squats also proved to be effective for the posterior muscles, where MU showed values of 33.3 ± 8.8% of MVC for the squat and 34.6 ± 12.5% for isolated trunk extension exercise. The muscles that showed differences were: RA, which activated 5.2 ± 4.5% of MVC during the squat and 23.4 ± 12.8% in the isolated exercise; and EO, with 8.9 ± 4.7% of MVC in the squat and 37.6 ± 14.2% in isolated exercises. This difference shows that these two muscles seem to be mo re used in this situation of trunk flexion compared to squats, agreeing with findings from previous studies.[13] Contrary to what occurred for MU, IO and IC, which were as activated during squats as in more specific exercises.

According to the conclusions drawn from this study, it was seen that the OE and RA muscles, which play prominent roles as agonists in trunk flexion, showed a limited contribution as stabilizers during the execution of the squat exercise. A unifying characteristic among all the muscles investigated within the scope of this study was their isometric recruitment during the squat exercise, explained by their dominant role in supporting the execution of the lower limbs. This propensity for limited recruitment may be attributed to the emphasis placed on lower limb activity in the exercise in question. On the other hand, the IO emerges as a prominent entity in stabilization during the squat exercise. Its considerable activation in this context is associated with its relevant engagement throughout the movement, in addition to its proximity to the transverse abdominal muscles, a key region for maintaining the integrity of the spinal column.[14] The most precise understanding of this mechanism, however, remains as a point of interest, since the amplification of instability does not always correlate with an increase in muscle activation.[5]

Through an electromyographic investigation, Hodges and Richardson[5] established that the transverse abdominal muscle is the first to be activated during movements of the lower and upper limbs, denoting its fundamental position in segmental stabilization. The findings of that study are in line with the results obtained here, reinforcing the importance of the transverse abdominal muscle as a crucial component in maintaining stability, thus aligning with the findings presented here.

Boeckh-Behrens et al.[1] conducted a study using electromyography to evaluate a variety of exercises, aiming to discern which ones would be most effective in strengthening trunk muscles. The results of this study indicated that the squat ranked second among the exercises with the highest degree of recruitment of trunk stabilizing muscles. Notably, the muscles with the greatest role in trunk stabilization were MU, transversus abdominis and IO.[3,12,13]

The results obtained within the scope of this study have significant practical implications, since squats can be classified not only as a prominent exercise in strengthening the MU, IO and IC muscles, but also as an effective tool for this purpose. Additionally, squats emerge as an alternative that allows for the optimization of training time, since its implementation can lead to a reduction in the volume of exercises aimed at the aforementioned muscle groups (MU, IO and IC). This approach gains even more relevance considering the increasing emphasis given to the stabilization and safety of the spine within the scope of physical training. In the current context, the integrity of the spine has emerged as an area of primary concern for professionals in this sector, consolidating itself as a crucial aspect when conducting any form of exercise.[16]

The finding that certain individuals do not show a predisposition to perform exercises aimed at the abdominal and lumbar muscles, whether due to physical restrictions, medical reasons or even a lack of interest, reinforces the relevance of considering this fact when selecting the exercise. Squats to improve the strength of the MU, IC and IO muscles. In this context, squats emerge as a promising alternative, considering the potential for muscle recruitment and the possibility of overcoming any individual limitations.

To continue the investigations, we suggest exploring other exercises, also characterized by their complexity and considerable demand for postural control. This approach may prove productive in identifying equally effective alternatives for training spinal stabilizers, constituting a relevant topic for future studies.

Conclusion

This study provided significant insights into the effectiveness of the squat exercise in recruiting the muscles essential for stabilizing the trunk and protecting the spine. The robust and consistent results indicated that the squat is equivalent, in terms of effectiveness, to isolated exercises targeting the MU, IC and IO muscles, confirming that squats play an essential role in strengthening these groups. Muscle training has considerable practical implications for the field of resistance training and rehabilitation. The possibility of obtaining benefits similar to those provided by isolated exercises suggests that squats can be adopted as an integral and effective component in training programs aimed at trunk stabilization and spine security.

The results highlight the importance of diverse, research-based approaches to developing more effective training strategies. Continuous research in this field, exploring different variations and contexts of application of the squat, can contribute to optimizing exercise prescription and improving the therapeutic approach in the clinical and sporting context.

Authors' contributions

RS and GAB were responsible for conceptualization, data curation, investigation and, together with LB, methodology. LB and GAB were in charge of the administration of the project and wrote, reviewed and edited the article. GAB was also responsible for formal analysis, resources and supervision. All authors approved the final version.

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