
EFFECTS OF INCLUSION OF PROPRIOCEPTION TRAINING IN THE RECOVERY OF ADULTS SUBMITTED TO ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION SURGERY: A SYSTEMATIC REVIEW

EFEITOS DA INCLUSÃO DO TREINAMENTO DE PROPRIOCEPÇÃO NA RECUPERAÇÃO DE ADULTOS SUBMETIDOS À CIRURGIA DE RECONSTRUÇÃO DO LIGAMENTO CRUZADO ANTERIOR: UMA REVISÃO SISTEMÁTICA

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RESUMO

A ruptura do ligamento cruzado anterior (LCA) é a lesão de joelho mais frequente em adultos jovens, desencadeando consequências neuromusculares indesejáveis. Um programa de reabilitação bem estruturado com exercícios que ajudem a minimizar os efeitos deletérios dessas consequências são necessários, e o treinamento proprioceptivo tem sido proposto como um dos métodos de treinamento/reabilitação em pacientes submetidos a reconstrução do LCA. Assim, esse estudo teve como objetivo analisar por meio de revisão sistemática de literatura os efeitos da inclusão do treinamento proprioceptivo sobre diferentes desfechos (estabilidade/equilíbrio, propriocepção, força, capacidade funcional, coordenação) após cirurgia de reconstrução de LCA em adultos jovens. A busca dos artigos incluiu estudos produzidos nos últimos dez anos, sendo a busca realizada no mês de novembro de 2018. Foram conduzidas buscas nas bases de dados eletrônicas PubMed e Science Direct com a seguinte estratégia de busca: (("Proprioception"[Mesh] OR "Proprioception"[Text Word])) AND ("Anterior Cruciate Ligament"[Mesh] OR "Anterior Cruciate Ligament Reconstruction"[Mesh] OR "Anterior Cruciate Ligament Injuries"[Mesh]). Seis estudos foram selecionados para análise e os resultados mostraram que não há evidências científicas suficientes que mostrem os efeitos positivos da inclusão do treinamento proprioceptivo após cirurgia de reconstrução de LCA em adultos, tendo em vista a escassez de estudos, as discrepâncias nos achados, no tempo de intervenção e nos testes utilizados nas análises das variáveis.

Palavras-chave: Lesões do ligamento cruzado anterior. Propriocepção. Educação física e treinamento.

ABSTRACT

Anterior cruciate ligament (ACL) rupture is an injury in young adults, triggering undesirable neuromuscular effects. A rehabilitation program is structured with exercises that aid in intensive care training, and proprioceptive training has been proposed as one of the training/rehabilitation methods in patients undergoing ACL reconstruction. Thus, this study aimed to analyze, through a systematic literature review, the effects of including proprioceptive training on different outcomes (stability/balance, proprioception, strength, functional capacity, coordination) after ACL reconstruction surgery in young adults. The search of the articles included studies in the last ten years, being a search conducted in November 2018. Searches were conducted in the electronic databases of PubMed and Science Direct with a following search methodology: (("Proprioception" [Mesh]) OR "Proprioception" [Word Text]) AND ("Anterior Cruciate Ligament" [Mesh] OR "Anterior Cruciate Ligament Reconstruction" [Mesh] OR "Anterior Cruciate Ligament Injury" [Mesh]). Six studies were selected for the analysis and the results obtained there is insufficient scientific evidence showing the positive effects of training in proprioceptive training after ACL reconstruction in adults, in view of a shortage of studies, such as discrepancies in findings, without time of intervention and in the tests contracted in the analysis of the variables.

Keywords: Cruciate ligament lesions. Proprioception. Physical education and training.

Introduction

Rupture of the anterior cruciate ligament (ACL) is the most common knee injury, mainly in adults between 20 and 29 years old, mainly in sports that involve spinning, jumping, and direct contact between opponents¹. Neuromuscular consequences of ACL injury are important considerations, because they play a crucial role in recovery after ACL injury or

reconstruction², especially in knee extensor strength, neuromuscular control and proprioception³. A well-designed and scientifically based rehabilitation program plays a crucial role in the recovery process, especially in athletes, as they need to be able to return to sport as soon as possible to perform their duties, even so, authors have reported that athletes' performance can be impaired within two years after their return^{4,5}. As a way to minimize the negative consequences of ACL rupture after its reconstruction, studies have tested different protocols in its rehabilitation^{6,7}. In the case of postoperative rehabilitation, it is suggested to start with passive range of motion and weight-bearing activities immediately after surgery, and, in addition, proprioceptive exercises and muscle strengthening are also started during the first weeks, with progression as tolerated. Neuromuscular control exercises are gradually inserted to include dynamic stabilization, and controlled instability training between two to three weeks after surgery. Once satisfactory strength and neuromuscular control have been acquired, functional activities such as running and jumping can begin between 10 to 12 weeks and 16 to 18 weeks after surgery, respectively⁸.

Among the objectives of rehabilitation after ACL injury, is the restoration of the patient's joint stability, to enable him to return as safely as possible to the unrestricted levels of activity prior to the injury⁹. In the case of physical exercises, in a systematic review, the authors confirm that proprioceptive and balance exercise can improve results in people with ACL deficiency, and that modest benefits are apparent for people who have undergone ACL reconstruction¹⁰, due to the stimulation of the mechanoreceptors in the joint structures, which stimulate the sensitivity of the muscle spindles around the joint and create a state of "awareness" of the muscles to respond to the forces applied to the joint and, thus, improve the stability of the active joint¹¹.

Despite the importance of these findings, no study in the past ten years has been found in the literature comparing the isolated effects of proprioceptive training in individuals undergoing ACL reconstruction surgery. In order to find indicative of the effects of proprioceptive training, this review aims to analyze, through a systematic literature review, the effects of including proprioceptive training on different outcomes in young adults, after ACL reconstruction.

Methods

Procedures

This systematic literature review and the realization of its methodological steps followed the indications of the PRISMA model – Preferred Reporting Items for Systematic Reviews and Meta-Analyses¹². The search for articles included studies produced in the last ten years and was carried out in November 2018. It was carried out by two researchers independently and, when there was no consensus among reviewers on the inclusion of manuscripts in the study, they met and consulted a third researcher who evaluated the work and defined whether or not to include it in the review. To access the studies, searches were conducted in the electronic databases PubMed and Science Direct. The terms of the Medical Subject Heading (MeSH) database were used, with the following search strategy: (("Proprioception" [Mesh] OR "Proprioception" [Text Word])) AND ("Anterior Cruciate Ligament" [Mesh] OR "Anterior Cruciate Ligament Reconstruction" [Mesh] OR "Anterior Cruciate Ligament Injuries" [Mesh]). In addition to the search for descriptors, the names of authors who write about the topic (Akbari A, Baltaci G, Fu CLA, Moezy A, Ordahan B and Pistone EM) were searched, in order to retrieve research found in the references of the studies included in the review. Initially, the articles were evaluated by titles, then another evaluation was carried out, in the abstracts of all articles that met the inclusion criteria or that did not

allow for certainty that they should be excluded. After analyzing the abstracts, all selected articles were obtained in full and subsequently read in full.

The included articles were evaluated and classified according to the methodological rigor used, using the Physiotherapy Evidence Database (PEDro) scale¹³, which aims to identify studies with good internal validity and with sufficient statistical information so that the results of the interventions are interpreted with greater consistency. This scale is composed of 11 questions with dichotomous answers (yes and no) and, the greater the number of questions presented in the studies (answer yes), the better their design and their interpretation facility, having as a cut-off point the minimum score of seven points (seven questions). In addition, the following inclusion criteria were considered for the review: (I) original articles published in peer-reviewed journals; (II) studies published between January 2008 and November 2018; (III) sample with individuals submitted to anterior cruciate ligament surgery; (IV) adults; (V) used proprioception training in recovery; (VI) inclusion of a control group and (VII) having a minimum score of seven points on the PEDro Scale.

After evaluating the studies, the main results were extracted and tabulated in an Excel 2010 spreadsheet (Microsoft®, USA). Finally, data were extracted from articles that met the inclusion criteria, and data extraction was performed by the same independent evaluators. The data of the included articles were presented in textual and tabular form considering the variables of interest, and organized in chronological order, considering the year of publication. To present the descriptive data, absolute values, minimum and maximum values for some variables were used, as well as averages and standard deviation.

Results

Figure 1 shows the flowchart of searches and debugging. Of the six articles remaining after successive analyzes, none obtained a minimum score on the PEDro scale and were excluded. As for methodological quality, three articles scored seven points, one article eight points, and two articles reached nine points.

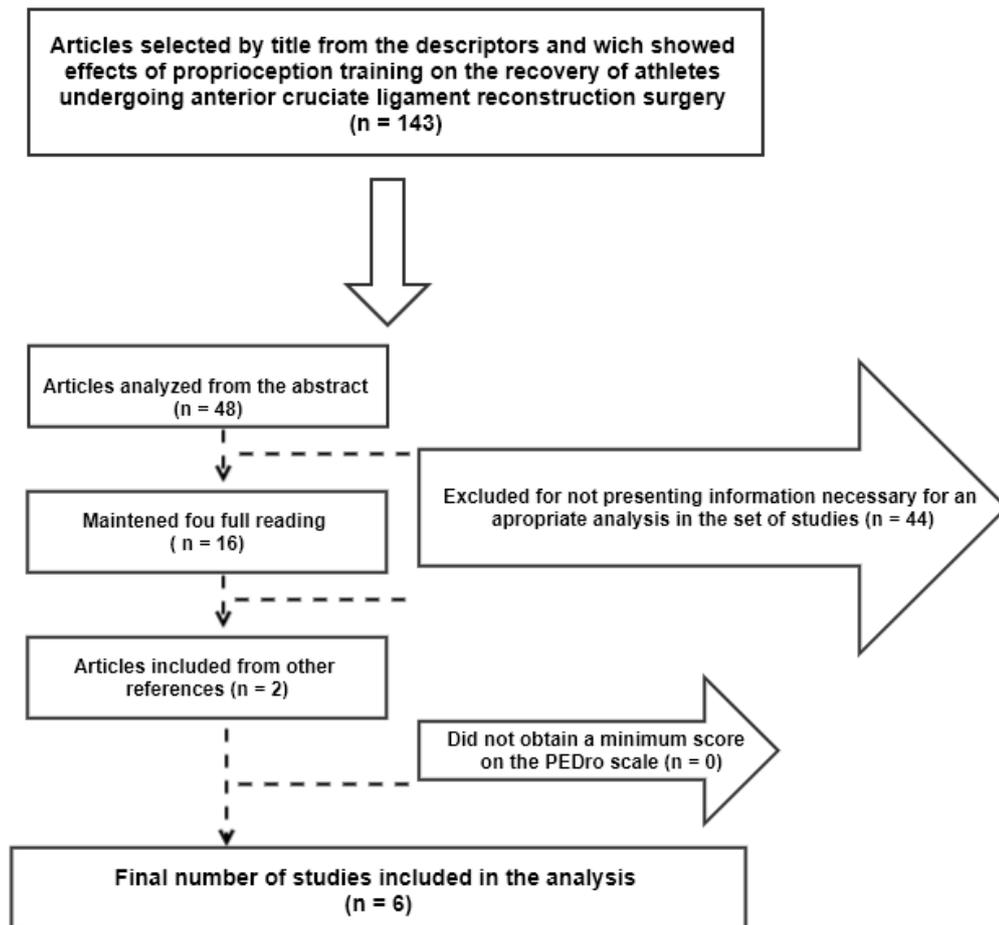


Figure 1. Flowchart of procedures for selecting articles included in the final study analysis
Source: The authors

Study	Objective	Method		
		Sample (N)	Experimental Design	Conclusion
Moezy et al. (2008)	To compare the effect of a whole-body vibration training (WBVT) with a conventional training program (CT) on knee proprioception and postural stability after anterior cruciate ligament (ACL) reconstruction.	IG = 10 CG = 10	The subjects in both groups followed a physical therapy program immediately after surgery for 12 training sessions. The subjects were randomly assigned to two groups (WBVT and CT groups) and started a weekly training program for four weeks three times a week.	It appears that WBVT had a greater somatosensory effect on balance control than conventional training. The main finding of this study was the positive effect of WBVT on improving knee proprioception and postural stability. WBVT can be used for the rehabilitation of patients after ACL reconstruction.
Baltaci et al. (2013)	Compare the effects of rehabilitation performed with Nintendo Wii Fit with those of conventional rehabilitation in subjects with ACL reconstruction.	IG = 15 CG = 15	The subjects were randomly divided into two groups. One group was trained with the Nintendo Wii Fit system (3x/week) and the other group with a conventional rehabilitation program after ACL reconstruction. Both programs lasted 12 weeks.	It is not clear that the Nintendo Wii Fit is significantly more effective in restoring neuromuscular control and increasing functional performance. Instead of conventional rehabilitation, the Wii Fit Balance program can be recommended as it is safe, viable and inexpensive.
Fu et al. (2013)	To investigate the early effect of WBVT on neuromuscular control after ACL reconstruction.	IG = 19 CG = 20	After surgery, the subjects were randomly assigned to the control or intervention group. In the control group, patients received conventional ACL rehabilitation, while patients in the intervention group received eight weeks of WBVT, in addition to conventional rehabilitation, one month after the operation.	The early start of WBVT from one month after the operation was an effective training method without compromising the range of motion of the knee and stability. Improved postural control, isokinetic performance, single-legged jump and agility, but not proprioception, triple jump and agility test with lateral movement (carioca test).
Akbari et al. (2015)	To evaluate the effect of a body balance training program on postural stability during the initial rehabilitation phase after ACL reconstructive surgery.	IG = 24 CG = 24	The subjects were recruited into two groups. In the intervention group, the subjects were trained with a balance training rehabilitation program for 30 minutes, 6 days a week, for 12 sessions (two weeks). Before and after interventions, in general, the anteroposterior and mediolateral stability indexes were measured in bilateral and unilateral support positions with eyes open and closed.	Proprioceptive exercise and balance improves postural stability in individuals with ACL in the initial phase of ACL reconstruction rehabilitation. These findings also suggest that neuromuscular training could be commonly used for patients with ACL reconstruction undergoing clinical treatment.
Ordahan et al. (2015)	Evaluate knee proprioception in patients with anterior cruciate ligament (ACL) injury and evaluate the effectiveness of an exercise program that consists mainly of proprioception exercises after ACL reconstruction.	IG = 20 CG = 16	The present participants were divided into two groups. One group included 20 male patients diagnosed with ACL injury who underwent a training program with proprioception exercises for 24 weeks, and the other group, consisting of 16 healthy volunteers matched for age and sex, who received no stimulus. Knee proprioception, pain and functional status were assessed in both groups before and six months after the intervention.	The rehabilitation program, consisting predominantly of proprioception exercises, provided considerable improvement in knee proprioception and functional status.
Pistone et al. (2016)	To evaluate the effects of adding a whole-body vibration protocol at optimal frequency (WBV-OF) to a traditional rehabilitation program (TRP) right after ACL reconstruction.	IG = 17 CG = 17	Participants were randomly allocated to the WBV-OF + TRP and TRP groups. Both the WBV-OF + TRP and the TRP group underwent the same conventional rehabilitation protocol, five days a week for the first 3 months of rehabilitation. However, the WBV-OF + TRP group also performed vibration training from the first to the second month after surgery, which performed three sessions per week for four weeks for a total of 12 sessions. The total duration of the program was 12 weeks, in both groups.	Adding four weeks of WBV-OF to a traditional rehabilitation program, one month after surgery is effective in improving the muscle strength of the knee flexor muscles. This early intervention can be incorporated into the current rehabilitation to facilitate the recovery of strength initiated in reconstructed ACLs.

Chart 1. Summary of the articles included in this review**Note:** IG: Intervention Group; CG: Control Group**Source:** The authors

Chart 1 presents the studies, their objectives, samples, methods, and main conclusions. The average time of study interventions was 10.3 ± 7.8 weeks; one study lasting two weeks (17), one lasting four weeks¹⁴, one lasting eight¹⁶, two lasting 12^{15,18} and the longest lasting was 24 weeks⁹. Only one study involved men and women¹⁶, and in total there were 207 participants who were randomized into an intervention group (received proprioceptive stimuli) and a control group. The one with the least involved 20 participants and the one with the largest number recruited 48 individuals. Regarding participation in the groups, 115 subjects were allocated to the intervention groups, and 92 subjects to the control groups. The average age of the participants was 25.3 ± 4.1 years, with 25 ± 4.1 and 25.7 ± 5.9 years for individuals in the intervention and control groups, respectively. Regarding the Body Mass Index (BMI), the general average was 23.8 ± 1.6 kg/m², and in a stratified way, the subjects submitted to the intervention had an average BMI of 23.3 ± 2.6 and a control group of 23.5 ± 2.2 . Only one study⁹ presented averages for both groups higher than the cutoff points established by the World Health Organization for the classification of eutrophy¹⁹.

Variables	Studies	Effect
Stability/Balance	AKBARI et al., 2015; BALTACI et al., 2013; FU et al., 2013; MOEZY et al., 2008 e PISTONE et al., 2016	= = ↑ ↑ =
Proprioception	BALTACI et al., 2013; FU et al., 2013; MOEZY et al., 2008; ORDAHAN et al., 2015	= = ↑ ↑
Force	BALTACI et al., 2013; FU et al., 2013 e PISTONE et al., 2016	= ↑ ↑
Functional Cap.	FU et al., 2013 e ORDAHAN et al., 2015	↑ ↑
Coordination	BALTACI et al., 2013	=

Chart 2. Effects of including proprioceptive training on different outcomes compared to the control group

Note: Functional Cap: Functional Capacity; =: There was no difference for the control group; ↑: Positive effect of including proprioceptive training compared to the control group

Source: The authors

Table 2 shows the effects of including proprioceptive training on different outcomes, with stability/balance being the most studied outcome. It can be analyzed that, only the functional capacity showed consensus of the results among the studies that analyzed it, showing superior effects of the inclusion of proprioception in the training, regardless of the chosen method. It should also be noted that the stability/balance analysis was the most analyzed variable, with five studies evaluating it in their respective participants^{14–16,18}. It is worth mentioning the absence of studies showing inferior effects of the inclusion of proprioception training in relation to the control group.

Discussion

The present systematic review aimed to investigate and synthesize the findings of investigations that analyzed the effects of including proprioceptive training after ACL reconstruction surgery in adults. All six selected studies^{9,14–18} evaluated their participants in two moments (pre and post intervention), but the outcomes assessed differed between them, which will be detailed below.

Regarding stability/balance, there is no consensus in the current literature on the positive effects of including proprioception training, in view of the four studies^{14–18} that evaluated this outcome. One study showed an intervention time of two weeks¹⁷, without significant results, using balance training, consisting of unilateral balance exercises with eyes

open and closed and ascending in front, posterior and lateral steps with both legs, with 30-minute sessions, six times a week, for two weeks, totaling 12 sessions and 360 minutes of training.

In the study that involved training on a vibrating platform for four weeks, three months after the ACL reconstruction of the participants (14), a positive effect was seen, with the same 12 training sessions from the previous study, but with a frequency of 3x/week. However, the time for training sessions started with 30 minutes in the first four sessions, 45 minutes from the fifth to the ninth session and 60 minutes from the tenth to the 12th session, thus increasing the total training time by 165 minutes in 45.8% of the time compared to the study by Akbari et al.¹⁷. Thus, the positive effect of proprioception on stability can be time-dependent.

Two other studies^{15,18}, with the same intervention time (12 weeks), did not show superior effects on stability/balance, from the inclusion of proprioceptive training, either through the Nintendo Wii Fit or through training on a vibrating platform, respectively. Finally, a study with eight weeks of training¹⁶ that compared a group with conventional treatment and another with the inclusion of the vibrating platform after one month of surgery, but tested after three months, it found superior effects on the stability/balance of this method compared to conventional treatment (control group).

The discrepancy between the results of the studies may be due to the balance test protocols used and the rehabilitation phase in which the interventions were performed. In general, therefore, these results suggest that any improvement in balance becomes evident after three months after the operation. Based on these findings, it can be suggested that several types of receptors are sensitive to the mechanical stimuli of the vibrating platform, with the most important effects of vibration being the stimulation of extraceptive receptors on the sole of the foot.

In addition, stimulation of proprioceptive receptors could initiate stretching and reflexes and, therefore, increase muscle strength. The nature of this repetitive stimulation may be a strategy to rearrange balance control, which results in improved postural stability²⁰. This may be due to the positive effects of the vibrating platform on muscle strength, better synchronization of firing of motor units and better co-contraction of synergistic muscles, which could bring better balance control^{21,22}.

In the case of proprioception, four studies^{9,14-16} evaluated this variable, two of which found positive effects of the inclusion of proprioceptive stimuli in the recovery of ACL^{9,14}. The work by Moezy et al.¹⁴ had an intervention time of four weeks and the stimuli were performed with a vibrating platform, three months after ACL reconstruction surgery, as mentioned above. The study by Ordahan et al.⁹, which lasted 24 weeks, included proprioceptive exercises from the third week onwards, with the degree of difficulty being progressively increased until the end of the training. In studies that did not obtain positive results in relation to the control group^{15,16} the intervention time was eight and 12 weeks, with training in the intervention group with Nintendo Wii Fit and vibrating platform respectively, and in this sense it seems that, like stability/balance, superior changes in proprioception with proprioceptive stimuli are also time-dependent.

According to studies^{8,23-25}, ACL rupture causes deficits in proprioception, variations in the pattern of muscle activity and progressive damage to the joint, in addition to loss of knee mechanics. Mechanical stability of the knee, although it is the main factor for knee recovery, does not seem to be sufficient for a satisfactory result of ACL reconstruction: a proprioceptive recovery also plays a significant role in the overall success of the reconstructive procedure. The main theoretical benefit of proprioceptive training is to improve the ability of the nervous system to synchronize the muscle activity of muscles that cross the knee joint, aiding in the dynamic stability of the joint.

For muscle strength, three studies were analyzed^{15,16,18}, two of which^{16,18}, presented effects superior to the control group, both with proprioception stimuli through vibrating platforms, with training frequencies between 35 and 50 Hz¹⁶, and median 35 Hz (interquartile range 30–45 Hz) in the work of Pistone et al.¹⁸.

Based on these findings, it is worth noting that higher frequencies (ie, 35, 40, 45 Hz) resulted in greater knee extensor activity²⁶. In addition, another study²⁷ demonstrated that a frequency between 26 and 44 Hz was used to improve muscle strength and that a frequency less than 20 Hz was used only for muscle relaxation and above 50 Hz were reported to cause muscle damage. The improvement in muscle strength in the two studies involving training with a vibrating platform supports the hypothesis outlined in the study by Fu et al.¹⁶ that early neuromuscular stimulation by this training method can improve muscle strength in ACL rehabilitation compared to conventional neuromuscular training programs.

Regarding functional capacity, the study by Fu et al.¹⁶ who used the vibrating platform as a form of training for eight weeks, evaluated single-leg jump, agility by the Shuttle-run test, triple jump and agility test with lateral movement (carioca test), six months after surgery, finding superior effects compared to conventional treatment (control group) for single-leg jumping and agility (Shuttle-run). In the study by Ordanhan et al.⁹, which compared the effects of 24-week proprioceptive training in subjects with ACL reconstruction versus healthy subjects who received no intervention, assessed functional capacity using the knee score test²⁸. This scale is validated and the knee score is related to symptoms that assess instability (25 points), pain (25 points), blockage (15 points), swelling (10 points), climbing stairs (10 points), signs of limping (5 points), support (5 points) and squatting (5 points), with a maximum score of 100 points, and the results were categorized as excellent (> 91 points), good (84–90), fair (65–83) or poor (< 65). The results show that training with proprioception exercises improves the average score values of the evaluated scale by 50.4%, however, in the statistical analysis there was no comparison with the control group. Therefore, the superior effects of training with a vibrating platform in relation to conventional training in improving functional capacity are highlighted and compared in the study by Fu et al.⁹, specifically in the unipodal jump and agility tests, tests that are directly related to muscle power, which in turn is related to muscle strength, which was previously described in this work, as well as the mechanism for such gain with vibratory training.

For coordination, only the study by Baltaci et al.¹⁵ evaluated and compared it with a control group, and the results showed no difference between the groups, remembering that the control group had the conventional treatment and the intervention group trained with Nintendo Wii Fit. However, introducing a game system in ACL rehabilitation can generate additional interest and motivation in therapeutic activities^{29–31} and can be used as a pleasant method to encourage physical activity^{32,33}.

Final considerations

We emphasize the need for studies that evaluate the isolated effects of proprioceptive training in individuals undergoing ACL reconstruction surgery, as well as research that also evaluates the effects of including proprioceptive training after ACL reconstruction surgery in adults, since the results found so far are inconsistent. In addition, it is necessary to conduct further studies to monitor and control the practice of physical activity by subjects throughout the day in individuals undergoing ACL reconstruction, in order to avoid positive or negative potential changes, either due to the type and time of physical activity performed during the day. In addition, there is a need for standardization of tests that assess different outcomes, considering that the extrapolation of results to different populations cannot be done.

Thus, this present systematic review showed that there is not enough scientific

evidence to show the positive effects of including proprioceptive training after ACL reconstruction surgery in adults, in view of the scarcity of studies, the discrepancies in the findings, intervention time and types of tests involved in the analysis of variables in studies currently found in the literature.

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