

Knee alignment with and without implements in leg press and squat exercises: a systematic review

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DOI: <https://doi.org/10.34256/ijpefs2121>

Received: 25-02-2021, Revised: 01-04-2021; Accepted: 02-04-2021; Published: 04-04-2021



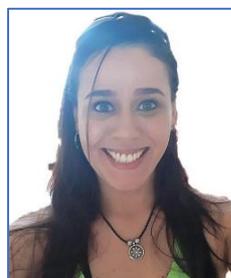
Abstract: Resistance training has been commonly used as a method of intervention in the rehabilitation of musculoskeletal injuries affecting the knee. Thus, the objective of this systematic review was to identify the methods employed with and without implements in leg press and squat exercises for the maintenance of knee alignment. The literature search was performed in the databases: PubMed, SciELO, and Lilacs. We used the descriptors "muscle strength" and "exercise" and their synonyms, available in the Health Sciences Descriptors (DeCS) and the Medical Subject Headings (MeSH), with the terms "valgus knee" and "varus knee". From the 1,117 articles found, eight studies were considered for the review. The included studies had samples composed of young men and women with advanced levels of training. Despite verifying conditions of valgus or varus knee, the studies presented different protocols and assessment methods. The implements comprised physio ball, elastic resistance, and wedge. Electromyography and kinematics were used to assess muscle activity and movement patterns. These results reinforced the possibility of using implements to induce muscle and joint actions to reduce varus and valgus conditions. We suggest more studies to define the best strategies to reduce the excessive deviation of the patella in people who have valgus or varus knee.

Keywords: Resistance training, Leg Press, Squat, Knee, Muscle strength.



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1. Introduction

Strength, hypertrophy, and performance gains can be obtained by the adequate prescription of resistance training (RT) [1]. RT can also be an alternative intervention method in the rehabilitation of musculoskeletal injuries affecting the knee [2]. Excessive misalignment of the patella is a very frequent type of lesion in the RT, especially in the squat exercise, which may be, among other factors, influenced by the valgus knee or dynamic varus [3, 4].

The main causes of deviations in the knee joint have been frequently studied [5], among which we can highlight the dynamic stabilization of the knee, which is ensured by the musculature that surrounds this joint [4]. The hip directly influences the kinematics of the knee as well as other adjacent joints. The weakness of the gluteus medius is also described as an important factor in the dynamic valgus, because it causes the fall of the contralateral pelvis, increased internal rotation, and adduction of the lateral femur [6]. The gluteus medius is an important hip abductor and its strengthening is constantly described in the rehabilitation of musculoskeletal injuries, as in patellofemoral dysfunction. Its strengthening can generate a decrease in the dynamic valgus [7].

Another existing deformity, which is more frequent in women, is varus knee [8]. This is characterized when the resulting abnormal compressive load increases the contact stress on the lateral tibial plateau to the detriment of the reduction of the contact area on the lateral plateau. Such imbalance of forces causes overload in secondary knee stabilizers, capsule elongation, lateral collateral ligament, and iliotibial band [9]. The stretching and tensioning of this band lead to weakness of the lateral muscle group of the thigh and, consequently, the loss of lateral stability [10].

Different techniques have been used in RT to inhibit valgism and varism [11]. However, it is necessary to highlight through the literature the main

findings regarding the RT on the stabilization of the knee joint and the respective methods used. Thus, this systematic review aimed to identify the methods employed with and without implements in leg press and squat exercises for the maintenance of knee alignment.

2. Materials and Methods

2.1 Study type

This review was drafted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations [12].

2.2 Inclusion criteria

We included studies that addressed the use of implements, such as ball and elastic band, during the execution of exercises for lower limbs, such as leg press and squat, for strengthening and stabilization of the knee joint in healthy participants of both sexes aged between 18 to 40 years, written in English or Portuguese. We excluded articles that presented in their methodology evaluation protocols rather than intervention and with injured individuals in the sample.

2.3 Search strategy

Initially, we used the descriptors and their synonyms "muscle strength" and "exercise", available in the Health Sciences Descriptors (DeCS) and the Medical Subject Headings (MeSH), and the additional terms "valgus knee" and "varus knee". The search phrase was established using the Boolean operators [OR] (between synonyms) and [AND] (between descriptors).

he searches were performed in the databases PubMed (US National Library of Medicine), SciELO (Scientific Electronic Library Online), and LILACS (Latin American and Caribbean Health Sciences Literature).

The search period was comprised between December 2018 and January 2021. The search strategy is presented in Table 1.

Following the inclusion criteria, the titles and abstracts were analyzed preliminarily, and those that were considered possibly eligible were recovered in their full version for a more accurate evaluation by two independent evaluators. The references of the original studies recovered were investigated to complement this review. When there was disagreement about the inclusion or exclusion of the article, a third independent evaluator was consulted.

3. Results

Of the 1,117 studies found through the search strategy, eight studies met the inclusion criteria of the present study. Figure 1 shows the selection process of the articles.

The characteristics of the participants in the included studies are summarized in Table 2. The total number of participants was 115 among men and women, although two studies did not specify the sex of the sample. The mean age of the participants ranged from 21 to 29 years.

Table 3 describes the procedural aspects, the objectives, exercises, implements used, evaluation instruments, and results of the studies that were reviewed. From the eight included studies, the leg press exercise was used in three [4, 13, 14] and the other five performed the squat exercise [15–19].

Table 1 Search strategy

Databases	Descriptors	Filters	Electronic addresses
PubMed	Muscle strength; resistance training; strength training; exercise; knee; dynamic valgus; dynamic varus; rehabilitation; hip abduction muscles; hip; knee muscles; quadriceps; Q angle; knee injury; elastic band; physioball; squat; leg press; leg exercise	Title, abstract	ncbi.nlm.nih.gov
Lilacs	Valgus knee; varus knee; exercise; strength training; knee	Title, abstract, subject	pesquisa.bvsalud.org
SciELO	Valgus knee; varus knee; exercise; strength training; knee	Title, abstract, keywords	search.scielo.org

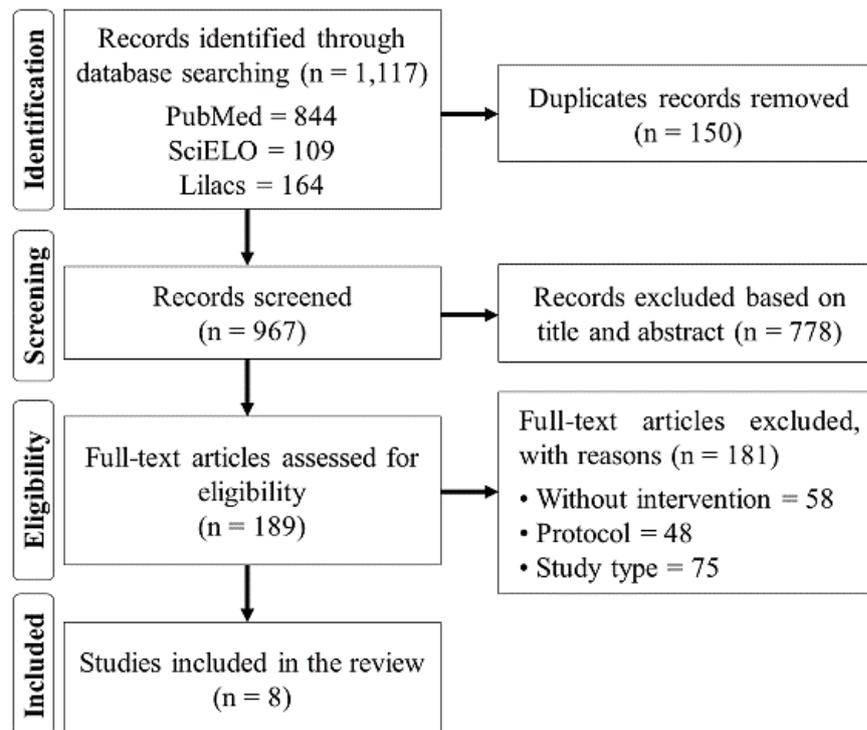


Figure 1 Flowchart of the selection process.

Table 2 Sample size, anthropometric characteristics, age, and training level of the participants included in the studies.

Study	Sample (n and sex)	Age (years)	Body mass (kg)	Height (cm)	Physical Activity Level
Paz <i>et al.</i> [4]	8 W	24.4 ± 2.1	65.1 ± 4.4	168.1 ± 4	Trained
Araujo and Silva Junior [13]	14 W	29.3 ± 7.5	84.1 ± 11.8	NR	Advanced level
Claiborne <i>et al.</i> [14]	30 (15 M and 15 W)	M: 26.4 ± 5.2 W: 23.5 ± 3.7	M: 84.1 ± 11.8 W: 66.0 ± 5.6	M: 176.9 ± 7.1 W: 170.9 ± 9.5	NR
Foley <i>et al.</i> [15]	16 M	T: 25.4 ± 4.4 U: 22.8 ± 1.6	T: 88.3 ± 12.5 U: 76.9 ± 9.2	T: 179.8 ± 8.8 U: 180.8 ± 6.0	T and U
Lee <i>et al.</i> [16]	20 (NR)	21.5 ± 1.1	57.95 ± 8.44	166.85 ± 9.26	NR
Peng <i>et al.</i> [17]	10 M	21.0 ± 1.4	70.8 ± 9.0	174.4 ± 7.1	Advanced level
Forman <i>et al.</i> [18]	7 (NR)	23.9 ± 2.4	86.8 ± 14.7	178.8 ± 9.4	Trained
Silva <i>et al.</i> [19]	10 M	NR	63.86 ± 6.02	172 ± 0.06	Trained

Table 3 Methodological characteristics of the included studies

Study	Exercise / Implemen ts	Instrument s	Procedures	Results
Paz <i>et al.</i> [4]	Leg 45° (Physioball and EB)	EMG BF, VL, VMO, RF	4 sets with 70% of 10RMS for each protocol: Control Physioball; EB	↑ C _{RMS} level of BF, VL, and VMO when they used physioball and EB
Araujo and Silva Junior [13]	Leg 45° and extensive chair (EC)	Goniometer, 3D analysis	NR	Angle Q, when compared in LP and EC, changed with the increase Knee flexion, both for normal knees and for valgus
Claiborne <i>et al.</i> [14]	Single leg squat	3D analysis of the frontal plane of the knee	S1: squat with 60° of knee flexion and return to standing position; S2: Isokinetic, concentric and eccentric (hip abduction/adduction; knee flexion/extension)	Significant relationship between flexor/extensor/adductor/hip rotator, knee flexor, extensor strength
Foley <i>et al.</i> [15]	Free squatting with the bar on the back/ EB	3D analysis, medial collapse of knee, and EMG of GMa, GMe, VL, BF	Trained group, performed 3RM. Untrained group, repetitions until failure with bodyweight	During 3RM, the weight of the squat was not affected by the intervention of the EB. The trained group had a greater amplitude regardless of the band. During concentric phase, knee width index was significantly lower for 3RM squats
Lee <i>et al.</i> [16]	Squat free/ball between knees, EB, and wedge beneath the feet	EMG VL and VMO	NR	VMO EMG using wedge below the feet > B. E VMO EMG in conventional squat and with the wedge > than when they used the ball
Peng <i>et al.</i> [17]	LP / Medicine ball	EMG VMO, VL, and AL of the dominant limb	LP in 3 conditions: TLP, LPSM, and LPM using a medicine ball of 6kg. Concentric and eccentric	Motion angle, small to medium effect size was observed incorporating the isometric adduction of the hip during the LP as the VMO/VL ratio
Forman <i>et al.</i> [18]	Free Squat with the bar above the head (OHS). EB	3D analysis Bending angle EMG of the muscles: AT, VMO RF, VL, GMa, GMe	Each participant performed 1 set of 12 reps with EB in the knee and without EB in the knee	Knee flexion angle was higher when performed without EB. Mean knee width index (IL) was higher in the squat without EB, as well as the maximum IL. There was no difference between protocols
Silva <i>et al.</i> [19]	Squat exercise (physioball and EB)	EMG VMO, VL, RF, BF	Three protocols with the intensity of 50 and 100% of 10RM without the	The distance between knees in the control protocol was lower when compared to SI 50%, with SI 100% and with EB 100%. The distance between

use of implements (SI) and with the use the knees was also lower for the protocols physioball 100% and EB 100% compared to the SI 100% protocols. VMO presented greater activation in the SI 50% protocols and physioball 50% when compared to the EB 50% protocol

BF: biceps femoris; VL: vastus lateralis; VMO: vastus medialis oblique; RF: rectus femoris; AT = anterior tibial; GA: gastrocnemius; GMa: gluteus maximus; GMe: gluteus medius; RMS: average value of normalized square root; EB: elastic band; CRMS: coefficient of root mean square; EMG = electromyography; S: session; VL = vastus lateralis; LP: leg press; TLP: traditional leg press; LPSM: LP with submaximal isometric action; LPM: LP with maximal isometric action; TUT: time under tension; RM: repetition maximum; reps: repetitions; NR: not reported.

4. Discussion

This systematic review was to identify the methods employed with and without implements in leg press and squat exercises for the maintenance of knee alignment. The included studies [4,13–19] showed samples composed of young men and women with advanced levels of training. Despite verifying conditions of valgus or varus knee, the studies presented different protocols and assessment methods. All studies aimed to verify methods and implements that could help the muscles responsible for stabilizing the knee to avoid valgus and varus conditions. The implements used in the reviewed studies were physioball, elastic resistance, and wedge. Electromyography and kinematics were used as a technique for assessing muscle activity and movement patterns.

The leg press exercise was used in three reviewed studies [4, 13, 14]. In the study by Paz *et al.* [4], the objective was to investigate the performance during the RT performing the leg 45° exercise using physioball and elastic band in 4 sets of 10 repetitions maximum (RM) for each protocol. Peng *et al.* [17] analyzed the effects of the leg press (LP) exercise in 3 conditions: traditional LP, LP with submaximal isometric action (LPSM), and LP with maximal isometric action (LPM) using a medicine ball. In the study carried out by Araujo and Silva Junior [13], the authors analyzed the Q angle of the knee by analyzing the kinematics in 3 dimensions (3D) and the knee flexion angle through the goniometer when performing the exercise in just one protocol without external overload.

The five studies that analyzed the squat exercise also used different protocols [15–19]. Foley *et al.* [15] evaluated the effects of the elastic band on kinematics and muscle activity during free squat with the barbell.

3D analysis was used as a method of evaluating movement and electromyography to analyze electrical activity. To investigate the effect of the free squat exercise, Lee *et al.* [16] used intervention protocols such as elastic band, physioball, and wedge below the feet. Forman *et al.* [18] and Foley *et al.* [15] used free squatting with the bar on the back and the elastic band. Silva *et al.* [19] used three protocols with the intensity of 50 and 100% of 10RM with physioball and elastic band and without the use implements.

Despite not using implements during exercises, two studies aimed to verify the stabilization of the knee [13, 14]. In the study by Araujo and Silva Junior [13], the authors analyzed the Q angle of the knee during the leg press and the extensor chair. In their results, the Q angle, when compared to the two exercises, changed with the increase in knee flexion, both for normal and valgus knees. Claiborne *et al.* [14] used 3D analysis of the frontal plane of the knee to determine the relationship between the strength of the hip and the knee and the movement of the valgus knee during the squat exercise. As a result, they found a negative relationship between the maximum isokinetic torque of the hip abductors and the external rotators during movement. They also found a significant relationship between the hip flexor, hip extensor, hip adductor, internal hip rotator, knee flexor, knee extensor strength, and knee valgus position.

These results reinforced the possibility of using implements to induce muscle and joint actions to reduce varus and valgus conditions. Thus, six studies used implements to check possible influences on the movement pattern to reduce these conditions and possible changes in muscle activity. Paz *et al.* [4] found high levels of mean square root in BF, VL, and VMO coefficients (CRMS) when they used the physioball

implements and elastic band compared to the control protocol without implement. The authors concluded that the procedures performed can be good alternatives to reduce these deviations and stabilize the knee. The results by Paz *et al.* [4] differs from Peng *et al.* [17], who analyzed the effects of the leg press exercise (LP) under 3 conditions: traditional LP, LP with submaximal isometric action (LPSM), and LP with maximum isometric action (LPM) using a 6 kg medicine ball. Regarding the angle of movement, when incorporating the isometric adduction of the hip during LP, the size of the effect observed from the VMO/VL activation ratio was shown to be small to medium.

However, the results by Lee *et al.* [16] are aligned with the findings of Paz *et al.* [4] and misaligned with the results of Peng *et al.* [17]. In their investigation, when evaluating intervention protocols such as elastic band, physioball, and wedge below the feet, the authors did not find significant differences between the exercises compared to the activity of the vastus lateralis muscle. In the wedge squat exercise, significantly greater activity of the vastus medialis oblique muscle was found compared to the squat exercise with elastic band. The authors suggest that conventional squat exercise may be one of the useful interventions for patients with patellofemoral pain syndrome. These different results can be explained by the use of different exercises with different intensities and training levels.

Following this reasoning, different intensities were assessed by Foley *et al.* [15] when evaluating the effects of the elastic band on kinematics and muscle activity during free squats with the back bar in two intensities divided into trained and untrained subjects. The trained group performed 3RM, while the group of untrained individuals performed repetitions with bodyweight until failure. During 3RM, the squat weight was not affected by the intervention of the elastic band. The trained group had a greater range regardless of the band. During the concentric phase, the index of spacing between the knees was significantly lower for 3RM squats.

Silva *et al.* [19] also verified different intensities, however, the authors also compared the protocols without the use of implements, with the use of a ball and elastic band and with the static position (control). A shorter distance between the knees was verified for the control protocol compared to the implement without 50% and 100% of the maximum strength and 100% elastic. These results reinforce the condition of dynamic varus in the performance of the

exercise in these protocols. The protocol without implements 50% also showed a significant difference, being greater in relation to the ball protocols 50% and elastic 50%. There was also a difference in the protocol without an implement with an intensity of 100% with the protocols, ball 100% and elastic 100% ($p < 0.001$), these being with a shorter distance between the knees, demonstrating that both protocols were able to reduce the dynamic varus. Although both showed a reduction in the dynamic varus, the 100% ball protocol reduced the distance between the knees more than the 100% elastic protocol.

The limitations of the present systematic review were the lack of clarifications regarding procedural protocols and training level of participants in some studies. Another point not reported in the studies listed was the familiarization process of the participants with the exercises proposed in the investigations performed. The application of familiarization can reduce the errors associated with the learning effects, as well as its absence can interfere with the quality of the results obtained [4]. Moreover, we only used three electronic databases in our search. Although PubMed, SciELO, and Lilacs catalog a great number of scientific journals worldwide, it may be that some studies published in other journals not indexed in these databases were not included in this review.

5. Conclusion

From the revised studies, there was a high vulnerability of the methods applied for training aimed at strengthening and stabilizing the knee. Clarification was lacking regarding procedural protocols, level of training, and familiarization of participants with the protocols used. Thus, these studies may be considered insufficient to define the best strategies to reduce the excessive deviation of the patella in people with valgus or varus knee. Thus, it is opportune to carry out further studies to analyze the use of implements such as physioball and elastic band, verifying, in addition to muscular activation, variables such as time under tension and knee alignment in protocols with different intensities and volume of execution of the analyzed exercises.

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Acknowledgement

Nil.

Funding

No funding was received to carry out this study

Ethics approval

This study doesn't require ethics approval

Authors Contribution

Jurandir Baptista da Silva - Study design, methodology & wrote the paper; **Juliana Brandão Pinto de Castro** - Study design, methodology & wrote the paper; **Claudio Joaquim Borba-Pinheiro** - Designed the study and analysis, contributed to the data analysis, Supervision, Edited the manuscript; **Giovanna Moraes Ribeiro** - Study design, methodology & wrote the paper; **Danielli Braga de Mello** - Study design, methodology & wrote the paper; **Rodrigo Gomes de Souza Vale** - Study design, methodology & wrote the paper. All the authors read and approved the final copy of the manuscript.

Does this article screened for similarity?

Yes.

Conflict of interest

Nil.

Availability of data and material

No additional data are available

Informed consent

Not Applicable

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