

Effect of vibration foam rolling on the range of motion in healthy adults: a systematic review and meta-analysis

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Professionals use foam rollers to improve range of motion (ROM). Recently, a vibrating foam roller (VFR) that combines the vibration function with a foam roller (FR) has been used. The purpose of this systematic review and meta-analysis was to determine the effects of a VFR on the improvement of ROM in healthy individuals. A systematic literature search was carried out in five international databases: PubMed, Embase, PEDro, Cochrane Library, and Google Scholar. Eight clinical studies, composed of six randomized controlled trials and two randomized crossover trials that involved 230 healthy participants were selected for analysis. Methodological quality was identified using the PEDro scale. The mean scores, 4.75 ± 0.71 , of the eight included studies, were classi-

fied as fair. The results demonstrated that the VFR achieved better gains than the FR in improving ROM (standardized mean difference [SMD], 0.53; 95% confidence intervals [CIs], 0.29–0.77; $I^2 = 55\%$). The VFR was more effective in improving the ROM than the FR in the hip and knee joints (hip: SMD, 0.56; 95% CI, 0.28–0.85; $I^2 = 0\%$; knee: SMD, 0.86; 95% CI, 0.42–1.30; $I^2 = 79\%$). The VFR may be an additional option to improve the ROM in healthy adults and athletes.


Keywords: Flexibility, Foam rolling, Range of motion, Vibration foam rolling

INTRODUCTION

The range of motion (ROM) of a joint refers to the range within which the joint moves. Flexibility is the ability of a joint to move spontaneously with full ROM (Dantas et al., 2011). Limitation in the ROM or decreased flexibility may increase the incidence of injuries, muscle, and tendon tension (Gleim and McHugh, 1997), or the independence of people with neurological disorders (Harvey et al., 2003). It limits functional ability and decreases the quality of life (Stathokostas et al., 2012). To improve the ROM and flexibility, many people use the stretching method (Decoster et al., 2005; Harvey et al., 2002; Medeiros et al., 2016; Radford et al., 2006). However, stretching can cause problems in muscle performance (Behm et al., 2016; Simic et al., 2013). As an alternative to this problem, medical professionals use foam rollers (FRs) to reduce pain while improving the ROM (Cheatham, 2019). FRs are used as a form of massage that applies pressure to soft tissues using a person's own weight (Peacock et al., 2014; Pearcey et al., 2015).

FRs have been reported to have advantages in muscle performance and recovery (Weerapong et al., 2005), thereby, FRs compensate for the disadvantages incurred with stretching.

Recently, vibration foam rollers (VFRs) that combine the vibration technology with FRs have been used. Vibration stimulation primarily contributes to muscle activity, strength, and neural mechanisms (Cochrane, 2011). However, despite the recent surge in research publications on VFRs, systematic evidence derived from them is still lacking. In previous systematic reviews including FRs and VFRs quantitative data synthesis was not performed, and the effect size could not be determined (Behm and Wilke, 2019; Cheatham et al., 2015; Hendricks et al., 2020; Hughes and Ramer, 2019). In the meta-analysis, only one to three studies on VFRs were included and they were reported together with studies on FRs; hence, insufficient data was available to analyze the effects of VFRs (Skinner et al., 2020; Wiewelhove et al., 2019; Wilke et al., 2020). Therefore, the purpose of this study was to systematically review and evaluate the effects of VFRs on the improvement of

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the ROM in healthy individuals.

MATERIALS AND METHODS

Protocol and registration

This systematic review and meta-analysis was registered in the PROSPERO (no. CRD42021231413) database. We followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines while reporting this study (Liberati et al., 2009).

Eligibility criteria

The strategy of this systematic review and meta-analysis was determined according to the PICO (participant, intervention, comparison, and outcome) strategy. In this review, participants (P) were defined as healthy individuals. VFR was defined as the intervention (I) in the experimental group. The experimental group was compared (C) with the FR group. Outcome (O) was defined as the change in ROM and flexibility. Only studies involving randomized controlled trials (RCTs), randomized crossover trials and articles published in English were included. Studies were excluded if they were quasi-experimental studies (non-RCT, interrupted time series), observational studies (prospective and retrospective), case reports, reviews, or systematic literature reviews and qualitative studies, opinion pieces, editorials, comments, news, and letters.

Search strategy

In January 2021, two independent reviewers performed a systematic literature search. Articles relevant to the research question were identified using PubMed, Embase, PEDro, Cochrane Library, and Google Scholar. Each database was searched from the earliest available article until December 2020. As an example, the terms used for the PubMed search were: “Vibration Foam Rolling,” “Vibration Foam Roller,” “Vibration Rolling,” “Vibration Roller,” (“Vibration Foam Rolling” OR “Vibration Foam Roller”) AND (“Range of Motion” OR “ROM”), (“Vibration Rolling” OR “Vibration Roller”) AND (“Range of Motion” OR “ROM”), (“Vibration Foam Rolling” OR “Vibration Foam Roller”) AND “Flexibility,” (“Vibration Rolling” OR “Vibration Roller”) AND “Flexibility.” In Google Scholar, a hand-searching approach was used. We searched all the articles and extracted the appropriate publications.

Study selection

Two reviewers independently assessed the eligible studies by

screening the titles and abstracts. Duplicates were identified and excluded using Endnote×8. These two reviewers checked the full-text when necessary. In cases of disagreements, a consensus was sought between the reviewers, or the coauthor reviewer was asked to resolve the issue.

Data extraction and data synthesis

Data extraction was performed by two reviewers independently using a standardized data collection form that included the year of publication; first author; sex, age, weight, and body mass index of the participants; study design; use of vibration technology; intervention protocols; outcomes; and results (pre-post mean changes, pre-post standard deviation (SD) changes). If reporting was incomplete (missing SDs of the changes from baseline), missing data were imputed using the formula $SD_{\text{change}} = \sqrt{(SD_{\text{baseline}}^2 + SD_{\text{postintervention}}^2) - (2 \times \text{Corr} \times SD_{\text{baseline}} \times SD_{\text{postintervention}})}$ (Higgins et al., 2021), where correlation (Corr) = mean Corr of the included studies. In cases of disagreements, a consensus was sought between the reviewers, or the coauthor reviewer was asked to resolve the issue.

Quality assessment

Methodological quality was implemented by two reviewers independently, after assessing the items based on the PEDro scale. In cases of disagreements, the coauthor reviewer cast a decisive vote. The total score of the instrument is calculated using items 2–11, capturing potential sources of bias. Item 1 refers to the external validity of the trial and thus is not included in the total PEDro score. The PEDro scale determines the scientific validity of physical therapy clinical trials (excellent, 9–10; good, 6–8; fair, 4–6; poor, <4).

Statistical analyses

The meta-analysis was performed using the R 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria). In the meta-analyses, when comparing outcomes measured on different scales, the standardized mean difference (SMD) with 95% confidence intervals (CIs) was used. The results were considered statistically significant when $P < 0.05$. Heterogeneity across studies was tested using the I^2 statistic, which is a quantitative measure of inconsistency across studies. Studies were considered to have low heterogeneity when the I^2 statistic was 25%–50%, and those with an I^2 statistic >75% were considered to have high heterogeneity. A subgroup analysis was conducted for: (a) hip vs. knee vs. ankle; and (b) according to the outcome. A sensitivity analysis was used to remove each study individually.

RESULTS

Search results

A PRISMA flowchart of the study selection is shown in Fig. 1. A total of 93 records were identified with 14 records remaining after the duplicates were removed. Next, five records were excluded after screening the title and abstract, leaving nine articles for full-text review. Among the nine articles, one was excluded for the following reasons: the mean and SD could not be obtained ($n = 1$). Finally, eight records were included in our meta-analysis (Cheatham et al., 2019; De Benito et al., 2019; Han et al., 2017; Kim and Shin, 2020; Lee et al., 2018; Lim and Park, 2019; Lim et al., 2019; Romero-Moraleda et al., 2019).

Characteristics of the studies

The eight clinical studies, composed of six RCTs and two randomized crossover trials, involved 230 healthy participants aged 20 years or older. The number of participants in each study ranged from 15 to 45. One study including 20 participants investigated VFRs with a vibration frequency of 3,700 rpm (Han et al., 2017). In the other seven studies, comprising 200 participants, the vibration frequencies varied from 18 to 33 Hz (Cheatham et al., 2019; De Benito et al., 2019; Kim and Shin, 2020; Lee et al., 2018; Lim

and Park, 2019; Lim et al., 2019; Romero-Moraleda et al., 2019). The characteristics of the VFR protocols and the outcome measurements are presented in Table 1.

Methodological quality

The methodological quality of the eight included studies ranged from 4 to 6 out of 10 and their mean scores with a sum of 4.75 ± 0.71 , were classified as fair (Table 2). All studies had similar baseline values between groups and reported information about randomization, results of inter-group statistical comparisons, and provided both point measures and measures of variability. In contrast, only a few studies indicated participant, therapist, or assessor blinding.

VFR versus FR

The total result demonstrated that VFRs achieved better gains than FRs in terms of improving the ROM (SMD, 0.53; 95% CI, 0.29–0.77; $I^2 = 55\%$), as shown in Fig. 2.

Effect of VFR on the ROM in each joint

The subgroup analysis was based on VFRs for the ROM in the hip, knee, and ankle joints (Fig. 3). The results for the knee indicated that VFRs improved the ROM (SMD, 0.59; 95% CI, 0.24–0.95; $I^2 = 66\%$). In addition, significant differences were observed

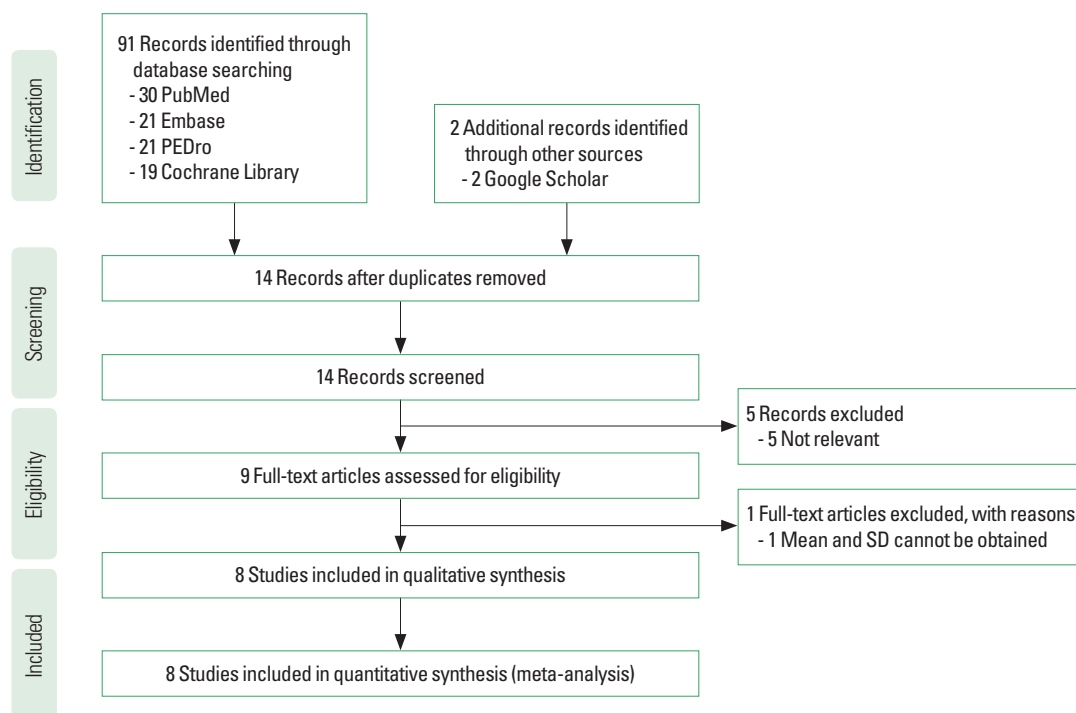


Fig. 1. Flowchart describing the study selection process.

Table 1. Characteristics of the included studies

Author	Design	Participants	VFR protocol	Vibration	Outcome
Cheatham et al., 2019	RCT 1. VFR (n=15) 2. FR (n=15) 3. CON (n=15)	n=45 recreationally active adults (male=27 and female=18) 1. 26.6±6.34 yr, 24.8±3.6 kg/m ² 2. 24.53±3.96 yr, 25.49±4.09 kg/m ² 3. 25.93±5.52 yr, 25.79±6.82 kg/m ²	VFR. 1×120s rolling quadriceps FR. 1×120s rolling quadriceps	33 Hz	Passive knee flexion ROM
De Benito et al., 2019	Crossover 1. VFR 2. FR 3. CON	n=15 healthy recreationally active participants (male=17 and female=7) 21.78±2.41 yr, 23.01±2.52 kg/m ²	VFR. 2×60s rolling quadriceps and hamstrings FR. 2×60s rolling quadriceps and hamstrings	30 Hz	Lunge ankle dorsiflexion ROM, sit and reach test
Han et al., 2017	RCT 1. VFR (n=15) 2. FR (n=15)	n=30 students of university 1. 20.50±1.09 yr, 62.58±8.5 kg 2. 20.6±0.83 yr, 66.41±16.45 kg	4 wk, 3 times a week, 1x20 min	3,700 RPM	Hip joint ROM (flexion, extension, internal rotation, and external rotation)
Kim and Shin, 2020	RCT 1. DVFR (n=12) 2. SVFR (n=12) 3. FR (n=12)	n=36 students of university (male=27 and female=9) 1. 22.33±2.3 yr, 67.83±12.53 kg 2. 21.5±1.44 yr, 69.67±12.12 kg 3. 21.75±1.36 yr, 69.5±12.15 kg	DVFR. 3×90s rolling hamstrings SVFR. 3×90s not rolling hamstrings FR. 3×90s rolling hamstrings	32 Hz	Modified active knee extension, stand to reach test
Lee et al., 2018	Crossover 1. VFR 2. FR 3. SS	n=30 male college students 20.4±1.2 yr, 68.8±8.9 kg	VFR. 3×30s rolling quadriceps and hamstrings FR. 3×30s rolling quadriceps and hamstrings SS. 3×30s static stretching quadriceps and hamstrings	28 Hz	Ely's test, popliteal angle test
Lim and Park, 2019	RCT 1. VFR (n=10) 2. FR (n=10)	n=20 college students (male=14 and female=6) 1. 20.21±1.01 yr, 63.67±11.1 kg 2. 21.72±2.16 yr, 68.93±17.16 kg	VFR. each 5×60s rolling both hamstrings FR. each 5×60s rolling both hamstrings	32 Hz	Active straight leg raising, active knee extension
Lim et al., 2019	RCT 1. VFR (n=8) 2. FR (n=8)	n=16 recreationally active persons (male=11 and female=5) 1. 20.37±1.06 yr, 20.85±1.48 kg/m ² 2. 20.75±1.39 yr, 22.68±4.19 kg/m ²	VFR. 5×60s rolling hamstrings FR. 5×60s rolling hamstrings	32 Hz	Sit and reach test
Romero-Moraleda et al., 2019	RCT 1. VFR (n=19) 2. FR (n=19)	n=38 healthy individuals (male=32 and female=6) 1. 21.9±3.7 yr, 75.26±8 kg 2. 22.2±3.2 yr, 69.7±11.4 kg	VFR. 5×60s rolling quadriceps FR. 5×60s rolling quadriceps	18 Hz	Passive and active hip extension and knee flexion ROM

VFR, vibrating foam roller; RCT, randomized controlled trials; FR, foam roller; CON, control; ROM, range of motion; DVFR, dynamic vibration foam roller; SVFR, static vibration foam roller; SS, static stretching.

Table 2. Assessments of methodological quality (PEDro scale)

Study	1	2	3	4	5	6	7	8	9	10	11	Total score
Cheatham et al., 2019	N	Y	N	Y	Y	N	N	N	Y	Y	Y	6
De Benito et al., 2019	N	Y	N	Y	N	N	N	N	N	Y	Y	4
Han et al., 2017	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Kim and Shin, 2020	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Lee et al., 2018	N	Y	N	Y	N	N	N	N	N	Y	Y	4
Lim and Park, 2019	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Lim et al., 2019	N	Y	N	Y	N	N	Y	N	N	Y	Y	5
Romero-Moraleda et al., 2019	N	Y	N	Y	N	N	Y	N	N	Y	Y	5

PEDro scale: 1, eligibility criteria were specified (this item is not used to calculate the PEDro score.); 2, participants were randomly allocated to groups; 3, allocation was concealed; 4, the groups were similar at baseline regarding the most important prognostic indicators; 5, there was blinding of all participants; 6, there was blinding of all therapists who administered the therapy; 7, there was blinding of all assessors who measured at least one key outcome; 8, measures of at least one key outcome were obtained from more than 85% of the participants initially allocated to groups; 9, all participants for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat;" 10, the results of inter-group statistical comparisons are reported for at least one key outcome; 11, the study provides both point measures and measures of variability for at least one key outcome.

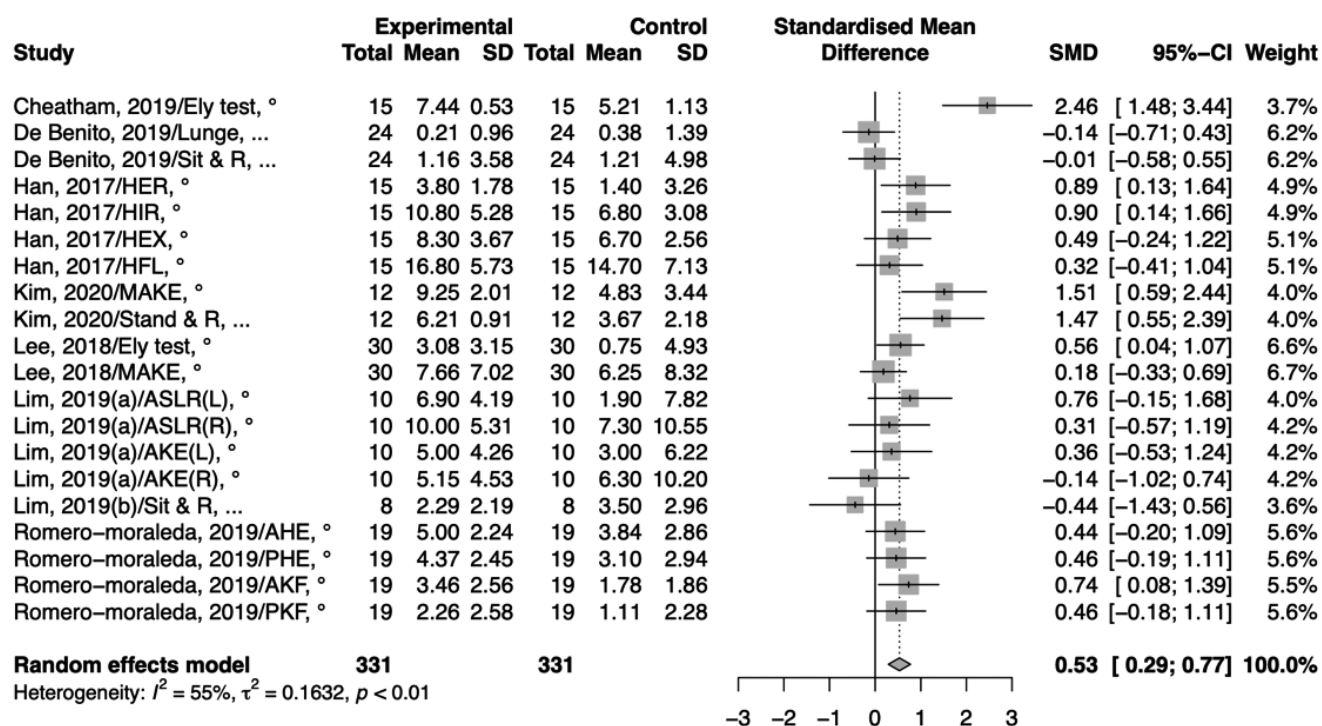


Fig. 2. Effects of vibrating foam roller (experimental) vs. foam roller (control) on range of motion. Forest plots with pooled standardized mean differences (SMDs), 95% confidence intervals (CIs) are displayed. SD, standard deviation.

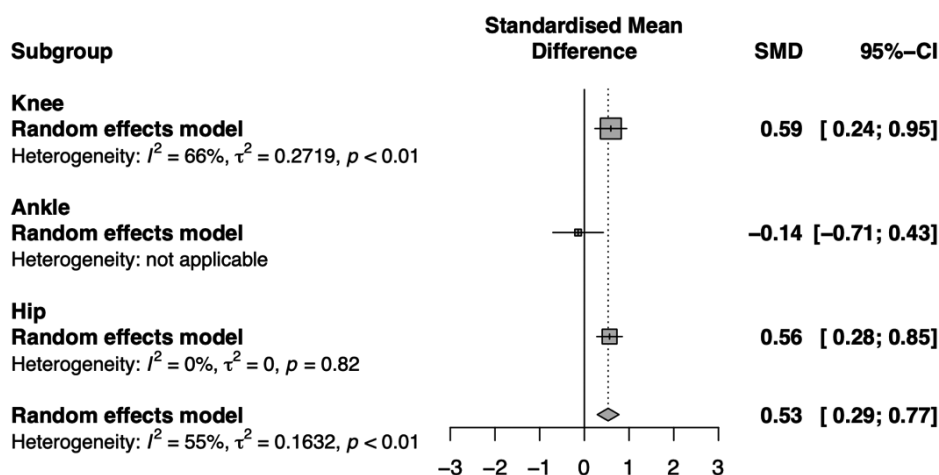


Fig. 3. Effect of vibrating foam roller for the range of motion in each joint. Forest plots with pooled standardized mean differences (SMDs), 95% confidence intervals (CIs) are displayed.

due to VFRs for the hip ROM (SMD, 0.56; 95% CI, 0.28–0.85; $I^2 = 0\%$). Furthermore, no significant differences were observed in VFRs for the ROM in the ankle (SMD, -0.14; 95% CI, -0.71 to 0.43). Heterogeneity was observed in the knee joints. There was no heterogeneity in the hip and ankle joints, or could not be confirmed.

Effect of VFR on the ROM in each outcome of the knee joint

To confirm the heterogeneity of the knee joint, a subgroup analysis was performed for each knee joint outcome (Fig. 4). Significant differences were observed in the stand & reach test and active knee flexion (AKF) (stand and reach test: SMD, 1.47; 95% CI, 0.55–2.39; AKF: SMD, 0.74; 95% CI, 0.08–1.39). No sig-

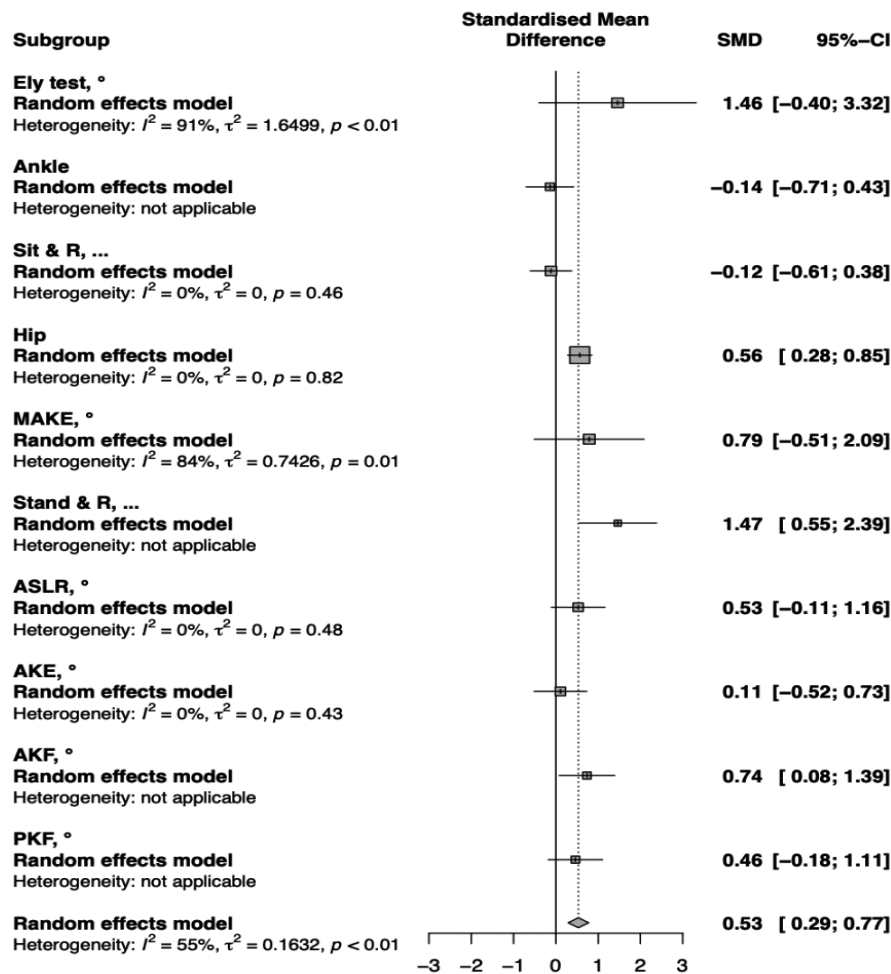


Fig. 4. Effect of vibrating foam roller on range of motion of each outcome knee joint outcome. Forest plots with pooled standardized mean differences (SMDs), 95% confidence intervals (CIs) are displayed. Sit & R, sit & reach test; MAKE, modified active knee extension; Stand & R, stand & reach test; ASLR, active straight leg raising; AKE, active knee extension; AKF, active knee flexion; PKF, passive knee flexion.

nificant differences were observed in the other outcomes. It was found that there was high heterogeneity in the Ely test and modified active knee extension (MAKE) (Ely test, $I^2 = 91\%$; MAKE, $I^2 = 84\%$). In the other outcomes, there was no heterogeneity or could not be confirmed.

Sensitivity analysis

When the results reported by one study (Cheatham et al., 2019) were removed from the study, the heterogeneity of 55% was lowest at 32% (SMD, 0.44; 95% CI, 0.25–0.64; $I^2 = 32\%$).

DISCUSSION

The use of VFRs has increased in recent years. However, direct evidence of its efficacy is still lacking. The results of this study

provide practical evidence for the effects of VFRs on the ROM in healthy adults. Our results showed that VFRs can induce greater improvement in the ROM compared to FRs. In a systematic review of FRs, a meta-analysis reported that there was no difference between the use of VFRs and FRs (Wilke et al., 2020). These results differ from the results of the present study. There was no significant difference in previous reviews (VFR vs. FR) due to the smaller number of included studies (three studies and four results) (Wilke et al., 2020). This study included more studies than previous studies, which we believe is the cause for the contrasting results (eight studies, 20 results).

Previous studies have reported only the overall effect without joint position-based (Wilke et al., 2020). In this study, subgroup analysis was performed based on joint position. It was effective in hip and knee joints, but not in ankle joints. The reason for this is

that the number of studies included in the ankle joint is small, and the study evaluating the ankle joint did not intervene VFR to the ankle but to the quadriceps and hamstrings (De Benito et al., 2019), so I think that the effect on the ankle joint did not appear. A study evaluating and intervention on the ankle joint is needed.

The VFR is a tool that combines vibrations with FR. The effects of FR and vibration are not known. There are several arguments regarding the mechanism by which FR improves the ROM (Behm and Wilke, 2019). Among the studies included in this analysis, a study claimed that vibration is more effective in improving blood flow (De Benito et al., 2019; Lee et al., 2018; Romero-Moraleda et al., 2019). Most of the referenced studies had included results that were based on whole-body vibration and not local vibration. Other previous studies compared the effects of VFRs and FRs in improving blood flow to the skin and reported that although they were more effective, there was no statistically significant difference (Lai et al., 2020). We consider that the pressure of the FR along with vibration worked synergistically to improve the blood flow. Another hypothesis was that vibration activates the muscle spindle and causes tonic vibration reflex (Cheatham et al., 2019; Lim and Park, 2019; Lim et al., 2019). This hypothesis was put forth based on the results of measurement after an intervention (vibration) but the results were not confirmed with the addition of vibration (Pamukoff et al., 2014). However, the mechanism of action for vibration is not clear. Therefore, further research is required.

The results of this study suggest that VFR was effective in improving the ROM but showed high heterogeneity. Although an additional heterogeneity analysis was not conducted, there was high heterogeneity in the outcome of a specific evaluation method. Regarding the methodological quality of this study, most of the studies were not completely blinded to the participants, therapists, and assessors. These results were considered to have influenced the increase in heterogeneity. Therefore, studies with better methodologies should be conducted in the future. There was a limitation of this study. The number of studies included was small, thus an additional heterogeneity analysis was not performed, and publication bias was not confirmed.

CONCLUSIONS

VFRs are more effective in improving the ROM than general FRs. These results indicate that VFRs may be an additional option for normal adults and athletes to improve their ROM. Further research must be conducted in the future to study their efficacy.

CONFLICT OF INTEREST

No potential conflict of interest to this article was reported.

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