The Effects of the Short Foot Exercise on Navicular Drop: A Critically Appraised Topic

Cameron Haun, Cathleen N. Brown, Kimberly Hannigan, and Samuel T. Johnson

Clinical Scenario: Deformation of the arch, as measured by navicular drop (ND), is linked to lower-extremity musculoskeletal injuries. The short foot exercise (SFE) has been used to strengthen the intrinsic foot muscles that support the arch. **Clinical Question:** Does the SFE decrease ND in healthy adults? **Summary of Key Findings:** Three studies that examined the use of the SFE on ND were included. A randomized control trial that compared the SFE to a towel-curl exercise and a control group found no significant differences between the 3 groups. A randomized control trial compared the SFE to the use of arch support insoles in individuals with a flexible flatfoot and found a significant improvement in the SFE group. A prospective cohort study, without a control group, reported a significant decrease in ND following a 4-week SFE intervention without a regression at an 8-week follow-up. Overall, two of the three studies reported a significant reduction in ND following an SFE. **Clinical Bottom Line:** There is preliminary data supporting the use of the SFE to decrease ND—particularly in individuals with a flexible flatfoot. However, issues with the study designs make it difficult to interpret the data. **Strength of Recommendation:** Due to limited evidence, there is grade B evidence to support the use of the SFE to decrease ND.

Keywords: clinical interventions, muscle activation, strength

Clinical Scenario

Excessive deformation of the arches of the foot is a concern for clinicians due to the resultant pathologic lower-extremity biomechanics.¹ Multiple studies have found that excessive arch deformation measured by navicular drop (ND), a common clinical assessment, is linked to several lower-extremity overuse injuries, such as medial tibial stress syndrome and patellofemoral pain syndrome.²⁻⁶ The protracted recovery and high rates of recurrence of these injuries not only pose a burden for the patient, (eg, pain, decreased performance, lost time) but also require additional resources (eg, time, money) from the clinician. Therefore, clinicians need interventions that will not only treat the symptoms but also address the underlying causes of the condition in order to prevent recurrence.

Because the arches of the foot are supported by both static and dynamic structures (eg, bones, ligaments, aponeurosis, and muscles), rehabilitation for conditions associated with deformation of the arch have included static support, such as orthotics, and dynamic support through strengthening of the muscles. One muscle group of particular interest is the intrinsic foot muscles, due to their role as an active stabilizer to the arches of the foot.⁷ An approach we have observed being utilized for overuse injuries associated with deformation of the arch is the short foot exercise (SFE). The goal of the SFE is to support the arches of the foot, specifically the medial longitudinal arch, by isometrically activating the intrinsic foot muscles.^{7,8} To perform the SFE, an individual is instructed to raise the medial longitudinal arch by bringing the metatarsal heads toward the heel without flexing the toes.⁹⁻¹¹ There is evidence that

the SFE results in increased dynamic balance control¹² and somatosensory function¹³ and greater activation of the intrinsic foot muscles compared with other common exercises.⁸ Therefore, a rehabilitation plan that incorporates the SFE may be effective in supporting the arch and resolving the condition. Unfortunately, to our knowledge, there has not been any research examining the use of the SFE in the treatment of specific conditions related to excessive arch deformation, such as medial tibial stress syndrome and patellofemoral pain syndrome. This makes it challenging for clinicians to judge the effectiveness of SFE in treating these conditions. However, because ND is a risk factor for several overuse injuries associated with arch deformation, a finding that the SFE is able to improve ND may provide initial evidence for the utility of the SFE in the prevention and treatment of these conditions.

Clinical Question

Does the SFE decrease ND in healthy adults?

Summary of Search, Best Evidence Appraised, and Key Findings

- The literature was searched for studies of level 2 evidence or higher¹⁴ that investigated the effects of the SFE on ND.
- The literature search returned 8 possible studies related to the clinical question. Three studies met the inclusion criteria: 2 randomized control trials^{9,10} and 1 prospective cohort.¹¹
- Lynn et al⁹ performed a randomized control trial comparing ND in healthy young adults after a 4-week intervention of SFE, towel-curl exercises, or a control group. They reported no significant differences between groups for either the dominant or nondominant leg.

Haun is with Providence Sports Medicine, Portland, OR, USA. Brown, Hannigan, and Johnson are with the College of Public Health and Human Sciences, Oregon State University, Corvallis, OR, USA. Johnson (Sam.johnson@oregonstate.edu) is corresponding author.

- Kim and Kim¹⁰ compared the ND of individuals with a flexible flatfoot following either a 5-week SFE intervention or an intervention consisting of wearing custom insoles 3 times a week for 30-minute intervals for the same 5 weeks. They reported a decrease in ND in the SFE group after the intervention but not in the insole group. In addition, the comparison of change scores between the groups indicated a significant difference between groups, with the SFE having a greater reduction in ND.
- Mulligan and Cook¹¹ measured ND in a cohort of healthy young adults following a 4-week SFE intervention. There was a significant decrease at the end of the intervention that was retained during a follow-up at 8 weeks. A post hoc analysis indicated that participants with an ND drop greater than 15 mm (ie, flexible flatfoot) demonstrated a greater improvement. However, there was no control or comparison group included in the study.
- Two of the 3 studies reported a decrease in ND following an SFE intervention. While the studies used different intervention volumes and progressions, the SFE instructions were consistent across the publications. This suggests that SFE may improve ND. However, the 2 studies with positive results either did not include or had an inadequate control group and also used statistical analyses that may have been inappropriate. Furthermore, no studies have directly assessed SFE in individuals with conditions associated with arch deformation. Therefore, the evidence should be considered preliminary.

Clinical Bottom Line

Preliminary evidence suggests that SFE improves ND in healthy adults, particularly in those with a flexible flatfoot. The evidence should be considered preliminary due to concerns related to the methods used in the studies. Specifically, the 2 studies with a positive outcome either had no control group, or the comparison group was inadequate to determine if the results were due specifically to the SFE intervention. In addition, the 3 studies included in the critically appraised topic (CAT) studied participants that were asymptomatic. However, available evidence suggests there are other positive benefits of the SFE, including increased dynamic balance control,¹² improved somatosensory function in ankle instability,¹³ and greater activation of the intrinsic foot muscles.⁸ Clinicians should use their best clinical judgment when deciding whether to utilize the SFE as an intervention for decreasing ND.

Strength of Recommendation

Due to inconsistent results in the studies used, there is grade B evidence to support the use of SFE to decrease ND.

Search Strategy

Terms Used to Guide Search Strategy

- Patient group: Healthy adults
- Intervention: SFE
- Comparison: Control group or pretest/posttest
- Outcome: ND

Sources of Evidence Searched

- Medline
- EBSCOhost
- CINAHL
- Cochrane Database
- SPORTDiscus
- Additional sources obtained via review of reference lists and hand search

Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies that investigated the use of the SFE
- Studies that used ND
- Level 2 evidence or higher¹⁴
- Limited to English language
- Limited to the past 10 years (2008–2018)
- Indexed in one of the above databases

Exclusion Criteria

- Studies that did not use the SFE as an intervention
- Studies that did not use ND

Results of Search

Three relevant studies^{9–11} were located and categorized as described in Figure 1 and Tables 1 and 2 (based on Levels of Evidence, Oxford Centre for Evidence Based Medicine, 2009¹⁴).

Best Evidence

The studies in Tables 1 and 2 were identified as the best evidence and selected for inclusion in this CAT.

Figure 1 — Summary of the article screening process.

Table 1 Summary of Study Designs

Level of evidence	Study design/methodology of articles retrieved	Number located	Reference
2	Randomized control trial	2	Lynn et al ⁹ Kim and Kim ¹⁰
2	Prospective cohort	1	Mulligan and Cook ¹¹

Implications for Practice, Education, and Future Research

The results of this CAT indicate preliminary evidence that the SFE intervention has a positive effect on ND. However, this result should be considered with caution due to important methodological differences in the studies and also due to the fact the clinically meaningful difference in ND is currently unknown (although an ND greater than 10–15 mm has been considered excessive.^{15,16})

The Mulligan and Cook¹¹ study found a significant difference in ND following a 4-week intervention that was retained after a 4-week retention period. Unfortunately, effect sizes were not reported, so it is unknown if the 1.8 mm (4-wk ND minus pre-ND) and 2.2 mm (8-wk ND minus pre-ND) decreases were clinically meaningful. However, in the discussion of the study, they reported that a post hoc analysis indicated the intervention had a greater impact on participants with a ND greater than 15 mm. It is important to note that the study did not include a control group, so it is unknown if the change in ND was due to the SFE, to the activation of the intrinsic foot muscles regardless of the exercise, or to a learning effect. In addition, the researchers included both limbs in the one-way repeated-measures analysis of variance without accounting for any issues of independence (an assumption of an analysis of variance).

The other study that reported a statistically significant difference in ND following an SFE intervention was the Kim and Kim¹⁰ study. This study was unique among the 3 studies included in the CAT, in that the participants all had an asymptomatic flexible flatfoot (ND > 10 mm). The researchers did include a comparison group. Specifically, participants in the comparison group wore arch support insoles for the same volume of time that the SFE participants performed the exercise (ie, 30-min sessions, 3 times per wk, for 5 wk). The SFE group had a 3.7-mm decrease in ND, and the insole group had a 1.7-mm decrease. Like the Mulligan and Cook¹¹ study, the effect sizes were not reported. In addition, while there was a comparison group included in the study, the focus of the 2 interventions was different—one focused on activation of the intrinsic foot muscles (SFE group), and the other focused on providing structural support through insoles. Therefore, it is difficult to know whether the improved ND in the SFE group was due specifically to the SFE or to the fact that one intervention targeted activation of a specific muscle group whereas the other did not. In other words, other exercises that target the intrinsic foot muscles could be just as effective. In addition, the statistical design (ie, multiple *t* tests instead of a repeated-measures analysis of variance) make interpretation of the study results challenging for the clinician.

The Lynn et al⁹ study did account for the fact there are multiple exercises with the potential to activate the foot intrinsic muscles. In addition to the SFE group, they included a towel-curl exercise group and a control group. There were no significant interactions or main effects for any intervention on either the dominant or the nondominant limb. They reported a 1.8-mm

decrease in navicular height on the dominant limb and a 1.3-mm decrease on the nondominant limb. While the differences were not statistically significant, the effect sizes for the dominant and nondominant limbs were -0.56 and -0.38 , respectively (effect size = $\frac{\text{post mean} - \text{pre mean}}{\text{pre standard deviation}}$). The towel-curl group had no change (effect size = 0.00) in the dominant limb and a 2.1-mm increase (effect size = 0.26) in the nondominant limb. The control group had a 0.4-mm decrease (effect size = -0.06) and a 0.3-mm decrease (effect size = -0.05) for the dominant and nondominant limbs, respectively. Taken together, although there was not a statistically significant difference between groups, the reported effect size for the SFE group could be considered moderate.

If clinicians decide to prescribe SFE, they may be interested in the SFE prescription in the studies. All 3 studies taught the SFE with the same instructions. In addition, the intervention length was relatively consistent across studies (ie, a 4- or 5-wk program). However, other elements of the exercise prescription varied between studies. Two studies had the participants perform the exercise daily,^{9,11} and the other study asked participants to complete the exercise 3 days per week.¹⁰ The duration of the contractions were 5 to 10 seconds in all 3 studies, but the repetitions per session varied between 30 and 120. Taken together, this resulted in exercise volumes that ranged from 4200 to 18,000 seconds of contraction across the interventions. Interestingly, the 2 studies that reported a significant reduction in ND utilized the lowest and highest exercise volumes of the 3 studies. This indicates that the specific exercise volume is perhaps not as important as simply prescribing SFE in order to activate the intrinsic foot muscles.

Clinicians may also be interested in exercise progression. While all 3 of the studies began the SFE program with the participant in the seated position, the progression was different in each. The Kim and Kim¹⁰ study utilized the seated position throughout the 5-week intervention and reported significant results. The Lynn et al⁹ study instructed participants to progress to a standing position for the last 2 weeks of the intervention but did not find a significant change in navicular height. The Mulligan and Cook¹¹ study, which also reported a significant decrease in ND, instructed participants to self-advance from a seated position to a double-leg stance and eventually a single-leg stance when they were able to complete the full 3-minute session without increased soreness the following day. Participants in that study were also instructed to alter their visual status (open to closed) and change the stability of the surface (stable to unstable) that the SFE was performed on; however, it was not clearly indicated how these progressions were implemented.¹¹ Again, as with exercise volume, statistical significance did not seem to correspond to the demands of the progression. In other words, the study that did not include any exercise progression and the one with the most demanding progression both reported a significant reduction in ND. This suggests that exercise progression to more demanding positions may be unnecessary.

In conclusion, preliminary evidence suggests that SFE interventions may improve ND, with the greatest potential benefit to individuals with a flexible flatfoot. However, this should be

Table 2 Characteristics of Included Studies

Study Design	Kim and Kim ¹⁰		Lynn et al ⁹	Mulligan and Cook ¹¹	
	Randomized control trial	Randomized control trial	Randomized control trial	Prospective cohort	Prospective cohort
Participants	<p>Fourteen university students (10 male and 4 female) were randomly assigned to either an SFE or an ASI group. The SFE group included 6 males and 1 female (age 24 [1.9] y, height 172.2 [6.9] cm, weight 68.2 [12.9] kg). The ASI group included 4 males and 3 females (age 24.1 [1.5] y, height 167.0 [6.7] cm, weight 63.3 [17.6] kg).</p> <p>Exclusion criteria included performing lower-limb exercises independently, foot hypoesthesia, fracture, dislocation, skin disease, or vascular disease.</p> <p>Inclusion criteria included a flexible flatfoot, defined as an ND test with a 10 mm or larger difference.</p>	<p>Thirty participants were randomly assigned to 1 of 3 groups: SFE, TCE, or control group. Two participants from each group (n = 6) were removed from the study due to either failing to comply with exercises or not returning for follow-up testing, so each group included 8 participants. The SFE group included 3 males and 5 females (age 23.7 [2.1] y, height 172 [10] cm, weight 69.9 [9.8] kg). The TCE group included 4 males and 4 females (age 22.8 [1.2] y, height 169 [13] cm, weight 66.0 [11.2] kg). The control group included 3 males and 5 females (age 22.6 [1.7] y, height 174 [10] cm, weight 68.8 [9.4] kg).</p> <p>Exclusion criteria included low back or lower-extremity injury in the past 6 mo and a neurological deficit that would affect balance.</p>	<p>A convenience sample of 21 individuals (18 females and 3 males) participated in this study (age 26.1 [3.7] y, height 168.4 [7.1] cm, weight 69.3 [13.6] kg). A total of 42 feet were included in the study.</p> <p>Exclusion criteria included any sign of foot pain, history of patellofemoral pain syndrome, plantar fasciitis, anterior or posterior tibialis dysfunction, and evidence of systemic or neurological disease within the past 6 mo that would affect motor function or previous experience with the plantar intrinsic foot training used in this study.</p>		
Intervention Investigated	<p>The SFE group was instructed pull the head of the first metatarsal toward the heel without bending the toes while sitting with the hip, knee, and ankle joints all at 90°. The contraction was held for 10 s, followed by 5 s of rest. This was repeated for 30 min (with no prescribed rest periods) 3 times per week for 5 wk.</p>	<p>The SFE group was instructed to raise the arch by drawing the metatarsal heads towards the calcaneus without flexing their toes and then holding an isometric contraction for 5 s for each repetition. Individuals were instructed to perform 100 repetitions daily over the course of the 4 wk.</p> <p>For the first 2 wk, the exercises were to be done seated. At week 3, the participants returned to be instructed on how to perform the exercise while standing for the remaining 2 wk of the study.</p>	<p>The SFE group was instructed to perform an SFE without activation of the extrinsic leg musculature. Each repetition was held for 5 s and repeated for up to 3 min (approximately 30 repetitions) on each leg. During an initial 1-h training session, participants were instructed on how to properly perform the SFE and how to progress the exercise (seated to double-leg stance to single-leg stance, eyes closed to eyes open, and stable surface to unstable surface). The participants were instructed to increase the difficulty when they were able to perform the exercise for the full 3 min without increased soreness the following day. The program was unsupervised and was 4 wk in length. Compliance was recorded in an exercise log in which the participants recorded position, need for balance assistance, visual status, surface, and contralateral leg movements needed to maintain balance.</p>		
Control / Comparison	<p>The ASI group had custom practitioner-made insoles using 3.2-mm thermoplastic material. The patients were instructed to use the insoles in their shoes and walk 30 min on flat ground 3 times per wk for 5 wk.</p>	<p>The TCE group was instructed to place a towel on a slick surface with their toes at the edge of the towel, then pull the towel by flexing their toes and gripping for a 5-s hold for each repetition. Volume and progression were the same as the SFE group.</p> <p>The control group was instructed to follow-up at the same time as the experimental groups for serial measurements.</p>	None		

(continued)

Table 2 (continued)

	Kim and Kim ¹⁰	Lynn et al ⁹	Mulligan and Cook ¹¹
Outcome Measure(s)	ND was measured by measuring the height of the navicular tuberosity. First, with the participant in a seated position (knee at 90° and in line with their second toe to attempt to standardize subtalar joint positioning) and then standing with the feet shoulder width apart. The difference between seated and standing was the ND. An average of 3 trials was used.	ND was measured using a modified version of the ND test. A mark was placed on the navicular tuberosity of each foot. The participant was then instructed to stand with their legs straight with equal weight on each foot. Navicular height was then measured.	ND was measured bilaterally. The participant was seated with the foot in a subtalar neutral position. The most anterior and inferior portion of the navicular tubercle was marked. The subject held this position while the navicular height was measured with a digital caliper. Next, the participant was asked to stand in a relaxed stance position with approximately 90% of the body weight placed on the measured leg. To help maintain balance, the participant was allowed to toe-touch with the contralateral leg and use a dowel rod in the contralateral hand. No attempt was made to maintain the subtalar joint neutral. The steps for measuring navicular height were repeated in a standing position and the difference between the seated and standing positions was considered the ND.
Main Findings	No measure of intrareliability or interrater reliability was reported. Dependent <i>t</i> tests indicated a significant decrease in ND for the SFE group at posttest but not for the ASI group. An independent <i>t</i> test of change scores indicated that the SFE group exhibited a greater decrease in ND compared with the ASI group after the intervention.	All measures were done by the same practitioner for consistency with no intrarater reliability reported. No significant interactions or main effects for ND for either leg.	Intrarater reliability for ND was reported at 0.88. There was a significant decrease in ND at both 4 and 8 wk compared with baseline and no significant difference between 4 and 8 wk. A post hoc analysis indicated that participants with an ND drop greater than 15 mm (ie, flexible flatfoot) demonstrated a greater improvement.
Level of Evidence	2b	2b	2b
Validity Score (Downs and Black)	13/26	15/26	13/26
Conclusion	The SFE program was more effective than arch support in decreasing ND.	The SFE did not decrease ND compared with the other groups.	The SFE program was effective in decreasing ND and changes in ND were still present 4 wk after cessation of exercises.
Limitations	Thirty minutes of SFE with unreported rest time is unlikely to be clinically applicable. The comparison group only wore insoles for 90 min/wk, making it difficult to determine the true effect of SFE.	Use of a modified ND test that assumed no change in navicular height in non-weight-bearing stance. There was no explanation of instructions given to the control group.	Lack of control group makes it difficult to know if effect was due to SFE, activation of the intrinsic foot muscles regardless of exercise selection, or a learning effect. Authors doubled the sample size by including both feet of participants without any examination of independence of limbs. Exercise progression was self-guided with a large self-reported range for progression to single-leg stance (ie, 6–28 d).

Abbreviation: ASI, arch support insole; ND, navicular drop; SFE, short foot exercise; TCE, towel curl exercise.

interpreted with caution due to the aforementioned concerns. Specifically, the design of the 2 studies that showed a reduction in ND make it difficult to determine if the effects were specifically due to the SFE intervention. Future studies should utilize comparison and control groups in order to help answer this question. In addition, studying symptomatic individuals would also assist the clinician. Finally, future research could be performed to determine if a specific progression and/or threshold of exercise volume is needed. This CAT should be reviewed in 2 years to determine whether there is additional evidence that could change the clinical bottom line.

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