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The Effect of Tissue Flossing Technique on Sports and Injury Prevention and Rehabilitation: A Systematic Review of Recent Research

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Abstract Flossband, as a novel and effective tissue flossing technique, is becoming increasingly popular in the field of athletic training, sports injury prevention, and rehabilitation. The purpose of this literature review is to summarize updated evidence about the effects of flossband application on joint range of motion (ROM), pain, muscle tightness, strength, and physical functional performance as well as identify research gaps for future study. Google Scholar, PubMed, EBSCO, and Web of Science were used to search related articles. The keywords of floss bands, flossbands, floss band, tissue flossing, flossing band, voodoo floss band, voodoo floss bands, track floss, rock floss, life floss band, and Rogue voodoo floss were used to extract target articles. English journal articles, full-text available, and content related to outcome measures were included. Conference abstracts, books, case studies, guideline reviews were omitted. 23 full-text journal articles were included for further qualitative analysis after removing duplicates and deleting articles that violate the screening criterion. Flossband application on limbs, soft tissue, or joints with about 50% flossing tension or 150 mmHg wrapping pressure could have small to medium effects on the parameters of ROM, muscle stiffness, muscle strength, and physical function performance, and large effects on pain management. Most previous studies were mainly focused on the acute effect of flossband application on peripheral joints or soft tissues in healthy and active participants or well-trained athletes. Therefore, for future studies, more evidence is needed on the benefits of long-term flossband trunk application and concerning patients with various diseases.

Keywords Flossband, Pain Management, Range of Motion, Tightness, Strength, Physical Function Performance, Fascial Release

1. Introduction

High-energy sports are prone to sports injuries as a result of tissues being overused during intense sports activities. Repeated exposure to the high mechanical stresses associated with sporting activities promotes abnormal postural adjustments and myofascial injuries [1]. Inflammatory reactions to tissue injury can change the structure of myofascial tissues, thus causing discomfort and hypersensitivity, and reducing an athlete's range of motion (ROM), strength and performance [2]. Many therapeutic strategies have been used to prevent and cure sports injuries and dysfunctions caused by biomechanical deficiencies and overuse. A flossband treatment is among the most popular therapeutic interventions in sports [3]. The anecdotal usage of this treatment among athletic individuals is becoming a popular technique to increase joint ROM, enhance both injury prevention and recovery, and improve overall sports performance. The soft tissue flossing technique is a treatment tool and an optional strategy to assist in sports training [4]. A flossband is composed of multiple layers of natural rubber, with a thickness of more than 1 centimeter, and this technique is an easy-to-acquire skill by different occupational professionals [5]. In addition, flossband is cheap, convenient, flexible, and effective [6].

Over the past few years, flossband application has been more commonly used in the field of training or rehabilitation. Accordingly, researchers have concentrated on testing the effects of flossband application on joint ROM in different joints [7,8], muscle tightness [9,10], muscle strength [15,16], as well as physical function performance [8,11–13]. However, despite the apparent benefits found in the above parameters, there was no relevant literature review that integrated these different findings. Wrapping tension or compression pressure of flossband application was the key skill. By reviewing the previous studies, these studies investigated the effects of flossband application by using various flossing tensions or wrapping pressures, such as 50% stretch tension [5,14] and 150-200 mmHg wrapping pressure [15,16] on the different soft tissues or joints. However, they all observed similar outcome measures. Unfortunately, there is little evidence overall for this technique and the current evidence. Very few studies showed either positive or negative support for use of tissue flossing.

To date, several papers have been published about the effects of tissue flossing techniques on the functionality of the hamstring muscles [9], ankle ROM and tensiomyography parameters [16], or the healthy and impaired musculoskeletal system [17]. No such overview exists for the effects of flossing. Thus, an in-depth review on the effects of the tissue flossing method in sports injury prevention and rehabilitation is required. Going forward, the purpose of this literature review was to collect, analyze and summarize the recent research on the application progress of tissue flossing technique, as well as to provide updated evidence about the effects of applying flossing technique on the parameters of pain, joint ROM, muscle tightness and physical functional performance in sports and clinical practice. Moreover, this literature review also aimed to identify potential research areas for future studies on the tissue flossing technique.

2. Methodology

This review included research studies related to the outcomes of tissue flossing technique application on different peripheral joints and soft tissues in different groups of people, such as general healthy young people, athletes, or patients. Hence, our population consisted of studies across seven years from January 2014 to May 2021.

As part of the search strategy, Google Scholar, PubMed, EBSCO, and Web of Science were used to search the related articles. The keywords of *floss bands, flossbands, floss band, tissue flossing, flossing band, voodoo floss band, voodoo floss bands, track floss, rock floss, life floss band, and Rogue voodoo floss* were used separately or in combination to extract the target articles (**Table 1**). The articles were required to be journal articles that were published in English. Conference abstracts, related books, case studies, guideline reviews, unavailable full text or articles without any relationship to the content by reviewing titles and abstracts were excluded. In addition, articles which did not report the outcome measures of pain, joint range of motion, and functional performance were also omitted.

Table 1. Search Strategy.

Type of Database	Searching type	Result
PubMed	(floss bands) OR (flossbands)) OR (floss band)) OR (tissue flossing)) OR (flossing band)) OR (voodoo floss band)) OR (voodoo floss bands)) OR (track floss)) OR (rock floss)) OR (life floss band)) OR (Rogue voodoo floss)	195
EBSCO	AB floss bands OR AB flossbands OR AB floss band OR AB flossing band OR AB tissue flossing OR AB voodoo floss band OR AB voodoo floss bands OR AB track floss OR AB rock floss OR AB life floss band OR Rogue voodoo floss	14
Wed of Science	TI = (floss bands OR flossbands OR floss band OR flossing band OR tissue flossing OR voodoo floss band OR voodoo floss bands OR track floss OR rock floss OR life floss band OR Rogue voodoo floss)	19
Google scholar	"floss bands" OR "flossbands" OR "floss band" OR "flossing band" OR "tissue flossing" OR “voodoo floss band” OR “voodoo floss bands” OR “track floss” OR “rock floss” OR “life floss band” OR “Rogue voodoo floss”	182

2.1. Study Selection

Two reviewers worked on the task of article searching and article quality evaluation. On one aspect, they individually used the same keywords to search articles in these four search engine databases. Then, they reviewed the title, abstract and full-text articles according to the inclusion and exclusion criteria. Articles were included in this study when the content is about the effects of tissue flossing on different soft tissues and various peripheral joints such as hamstring, upper limb muscles, quadriceps, Achilles tendon, ankle joint, knee joint, shoulder joint, elbow joint, and so on. Additionally, the articles should be focused on the parameters of pain, joint range of motion, muscle tightness, muscle strength, and physical function performance. For the other aspect, the two reviewers independently used methodology checklists which were developed by the Scottish Intercollegiate Guidelines Network (SIGN) (https://www.sign.ac.uk/checklists-and-notes.html) to evaluate the quality of the articles [18].

3. Results

This research identified 415 related articles in total. Of these, 410 articles were obtained from databases of PubMed, EBSCO, Web of Science, and Google Scholar by using the related keywords and search strategies. In addition, 1 abstract and 4 journal articles were found from other resources. Next, 85 articles were removed due to duplication. After that, 307 articles were excluded because these articles were not in English, had unrelated content, were not journal articles (news, product introduction, advertising, or conference abstracts) or the full-text was unavailable. Finally, 23 full-text journal articles were included for further qualitative analysis by following the exclusion criterion and inclusion criterion through a rigorous screening process (see Figure 1). Table 2 summarizes the results of accessible studies.

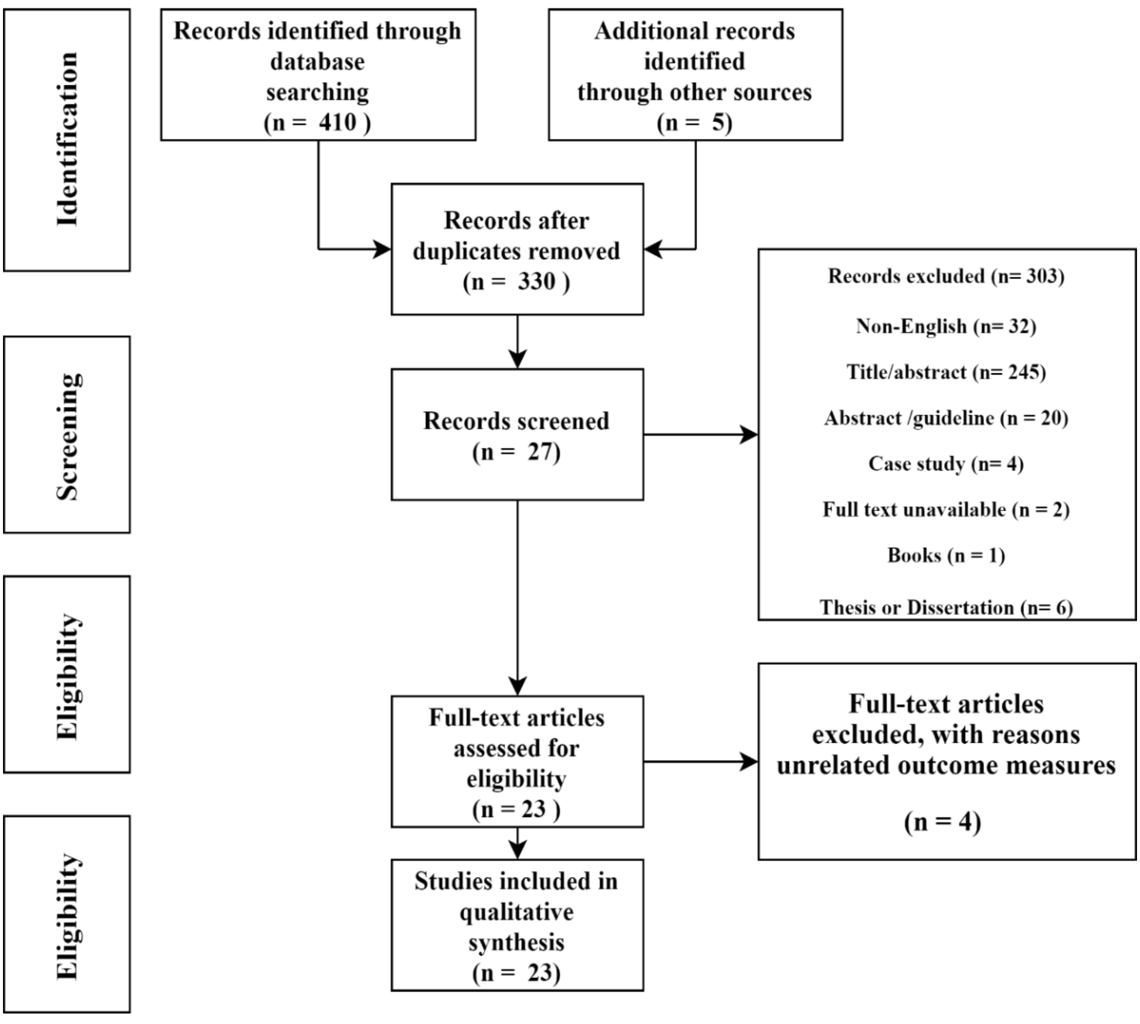

Figure 1. Searching result

Table 2. The result summary of previous studies

Author and year	Study design	Sample size/ group	Application part	Band and application	Test and Intervention	Outcome Measure	Conclusion
Driller [19]	Experimental	69 healthy recreational athletes (32 males and 37 females) Random split into two groups; Floss: 38 Control: 31	Ankle	Life Flossband Floss group: wrapped floss band on both ankles (figure 8 wrapping method on ankle) Control group: without floss band Compression force 178 ±18 mmHg	Pre-Posttest (post-testing were tested after 15, 30, and 45 minutes) Both groups were given standard 5 minutes' warm-up and bodyweight low limb dynamic stretch. Then floss group was applied flossband in both ankle and was asked to do 2 minutes' ankle full AROM of dorsiflexion and Plantar flexion. Control group was done the same exercise without flossband. After 2 minutes ankle exercise, two group were instructed to stand up and walk around for one minute and did the post-test	WBLT, CMJ, 5-m Sprint (secs) 10-m Sprint (secs) 15-m Sprint (secs).	No significance difference between floss group and control group during WBLT, CMJ and sprint, but there was a trend floss band benefit to ROM, CMJ and sprint performance. Significant improvement to WBLT after the application of CTF for up to 45 min.
Driller and Overmayer [15]	Experimental	52 healthy recreational athletes ((29 males and 23 females) Randomly assign; Floss group: 26 Control group:26	Ankle	Life Flossband Floss group: wrapped floss band on left/right side figure 8 wrapping method on ankle) Control group: without floss band Compression force 178 ±18 mmHg	Pre-Posttest (acute effect) Floss group: flossband was applied on one side of the ankle, and participants were asked to do both sides ankle full AROM of dorsiflexion and Plantarflexion, 20 repetitions within 2 minutes Control group: did the same exercise without applying flossband	WBLT, ROM(Dorsiflexion/plantarflexion), Single-leg jump height and velocity	No significant difference between the floss group and control group during WBLT, ROM, jump height and jump velocity, but it was a significant difference between pre and post-test in floss group.
Hagen [11]	Experimental	32 healthy college student (21 males and 15 females) Age: 22.1 ±2.4 Randomly assign into 4 groups: Control (without treatment) 8 DYN (CKC dynamic stretching) 8 STAT (CKC statistic stretching) 8 Floss (CKC dynamic combined with wrapping flossband) 8	Ankle	Rogue VooDoo Flossband (Columbus, OH) Floss group (figure 8 wrapping method on ankle)	Pre-Posttest (post-testing were testing immediate effect, 4, 8, and 12 minutes) Control: sat and rest 10 minutes DYN (20 reps/side, both sides, hold 1s-2s,2 sets) STAT (holds 45 seconds/side, both sides, 2 sets) Floss group (wrapped flossband on both ankles, 20 reps/side, both sides, hold 1s-2s,2 sets)	DF ROM (Lunge test, seated open chain) Bodyweight overhead squat test	No significant differences among groups during these outcome measures. Significant improvement in floss group during ROM OF CKC DF and Bodyweight overhead squat test. Significant improvement in DYN during DF ROM OF CKC and OKC.

Table 2. Continued

Kiefer et al. [20]	Pilot	60 Healthy college students (18-24 years old) Randomly assigned into 2 groups Control group 30, Floss group 30	Upper Arm	Voodoo flossband Floss group (50% tension applied vertical to the deltoid and directly contact with skin on the dominant arm) Control group (applied underwrap directly to skin)	Pre-posttest Floss group (seated position, should stretch with wearing floss band, 30 secs/set, 5 set) Control group (seated position, should stretch with underwrap, 30 secs/set, 5 set)	GH flexion ROM in a seated position Participants' perception score of flexibility	No significant between groups during outcomes measures, but there was a significant between pre and post-test in floss group.
Ross and Kandassam [21]	Cross-over	10 healthy participants (male 5, female 5) Age: 23.8 $\pm$ 4.66	Achilles Tendon	Voodoo flossband (50% tension, from 2cm superior to the calcaneal towards much belly of gastrominus) Flossing two legs in a different session.	Pre-posttest (posttest included: immediately effect and after intervention 7 hours) There were two separate sessions. Randomly choose one side of ankle wrapping flossband for 150 secs and did full ROM DF exercises, such as deep squat and calf raise. Then after 72 hours of washout, another ankle applied the same method	DF ROM	A trend of immediate effect flossband intervention can be a benefit to DF ROM,
Stevenson [22]	Cross-over	5 recreational male athletes Who had Tightness, stiffness, heel pain, Achilles tendon pain or calf pain (Age: 18) Random assign into floss group and control group	Ankle	Flossband (180 mmHg, wrapped start at midfoot until inferior soleus)	Pre-posttest Both leg did 2 minutes' exercise (included ankle DF/PF/circle, calf raise, body weight squat) Floss group wrapped flossband to do the exercise, control group without any wrapping	Ankle ROM (DF, PF), WBLT with knee SL and BL, TIGHT	There was significant difference between floss group and control groups during DF ROM, and there was a trend flossband that may help WBLT comparing with the control group.
Williams [23]	Experimental	16 healthy participants (Male:4, Female:12), randomly assigned into: Control:5 people IASTM:6 Floss group 5	Ankle	Floss group: applied standard ankle tape method (8 figure) Wrapped non-dominant ankle	Pre-posttest (posttest was tested after intervention 1W, 2W, 3W and 4W) Control group: calf stretch 30 secs/set, 3 sets (Slant board), calf raise exercise 10reps/set, 3sets, 2/week, 4 week IASTM applied HawkGrips IASTM tools for 5 minutes, and then did the same exercise like control group, 2/week, 4 week Floss group: 2 sets of 20 DF and PF with applying flossband, and then did the same exercise that the control group did.	Ankle DF ROM	There was no significant difference between groups during ankle DF ROM over time, but there was a significant improvement over time in each group.

Table 2. Continued

Cheatham [5]	Experimental	30 participants (male 15, female15) randomly assigned into: Foam roller group: 10 Soft tissue mobilization group:10 Floss group: 10	Thigh	Rockfloss® Flossband 50% tension Applied from upper patella to AIIS.	Pre-posttest Foam roller group: left side quadriceps release by using foam roller 2 minutes Soft tissue mobilization group: tool of soft tissue mobilization on left side quadriceps, inclined 45 °on the skin, 2 minutes Floss group: flossband wrap covered the quadriceps muscles above the patella to below AIIS combined exercises (hip flexion 30secs, knee flexion and extension 30secs, bodyweight squat1 minutes), (50% tension), 2 minutes	Knee flexion PROM	There was significant improvement during knee flexion PROM after intervention among three groups. There was no significant difference between groups, but floss group has improved knee PROM a lot than the other group.
Galis and Cooper [24]	Experimental	30 healthy participants (16 males, 14 female) randomly assigned into: control group 10 $FLOSS_{150}$ group: 10 $FLOSS_{200}$ group:10	Calf	Applied from above 5cm ankle joint to tibia tuberosity with 50% tension on right calf or left calf. Control group (underwrap pressure applied at, 5 mm Hg) FLOSS150 group: flossband pressure applied at 150 mmHg $FLOSS_{200}$ group: flossband pressure applied at 200 mmHg	Pre-posttest Applying Flossband or underwrap combined active - ankle ROM PF and DF exercises, 2 minutes, and then did 20 repetitions of calf raise exercise.	Ankle ROM DF, PF peak torque power	There was no significant difference between groups during these outcome measure. There was significant difference in $FLOSS_{150}$ group during DFROM, but there was improvement trend of DF power.
García-Luna [7]	Pilot	5 male athletes (Age: 20 ±0.5) with PFPS	Knee joint	Life Flossband Wrapping flossband around the knee joint from proximal to distal (182 ±38 mmHg).	Pre-posttest (wrapped flossband, remove flossband immediately test) Test would be executed into two days. In the first day, all participants were accepted CMJ (repeat three times and take the average) and VAS test before formal study, then they were wrapped by flossband around the knee and did the same test, after that they were removed the flossband and did the same test. In the second day, all participants did the same test but without applied flossabnd during three parts of testing. 1-minute rest between series, and 15 seconds between epetitions.	VAS CMJ (jump height, jump velocity, jump power, jump force)	There was significant improvement in all outcome measure between pretest and posttest. There was no significant difference without fossband during the second day testing.

Table 2. Continued

Kaneda [9]	Experimental	20 healthy young men (age: 22.5 ± 1.0)	Calf	Flossband (Sanctband COMPRE Floss TM Blueberry) Wrapped around calf muscles from above the ankle to under knee joint. (non-dominant leg,160 ±3 mmHg)	Pre-posttest (2 time * 3 intervention) All participants sited on the dynamometer of Cybex with knee extension and ankle fixed on the footplate, then they did DF by using Cybex at a velocity of 5 ◦ /s from GC-relaxed position to maximum most DF position which participants can most tolerate the GS stretch (I minute hold, 5 repetations). Then all participants rest 6 minutes on the isokinetic machine. After 7 days, all participants were wrapped flossband around calf, and they were given four times passive twisting the wrapped part and they were allowed to do PF and AF movement, 20 times.	DFROM, passive moment (0 °, 20 ° and at the end of ROM), fascicle length, muscle hardness, MVC, RFD (0-50ms, 0-100ms, 0-150ms and 0-200ms) and muscle activity	There were significant changes in RFD 0–50 and RFD 0–100 ms between Flossing and SS. The pre-post changes in DFROM was significantly higher with Flossing compared to Rest.
Kaneda [25]	Crossover	17 healthy young men (Age: 23.2 ± 1.1) Floosband was applied on hamstring of dominant leg	Thigh	Flossband (Sanctband COMPRE Floss Blueberry) Wrapped around hamstring muscles from above the knee to under AIIS.	Pre-posttest (2 time * 3 intervention) All participants went through three intervention pharse on three separate days. Phrase 1: All participants were given passive twisting and active knee flexion movement with the lower leg tightly wrapped flossband. Phase 2: They were given hamstring DS without flossband in upright position, 30 secs stretch, 4 sets, rest 20 secs Phase 3: only did active knee flexion movement without flossband.	SLR test, KE test, passive torque, passive stiffness, fascicle length, maximal isometric knee flexion contraction, maximal eccentric knee extension/flexion contraction, RFD, and muscle activity.	There were significant improvement in the SLR test, passive KE test, passive torque at end of ROM and maximal eccentric knee flexion contraction in flossband comparing control intervention.
Konrad [17]	Cross-over	16 healthy males (Age:25.69±4.1)	Thigh	Flossand （Ludwig Artzt GmbH, Dornburg, Germany） Wrapped 4.5–5 cm above the patella until the trochanter major (both thing), 50% tension	Pre-posttest Two conditions were randomly tested in different days （interval 48h） Warm-up 10 minutes. All participants were given 2 minutes flossband treatment (20 squats), after 48 hours, they were asked to do 20 squats without flossband.	ROM (hip flexion and knee extensor), MVC, PRT,CMJ	There were only significant effect on the MVC of the knee extensors between flossband condition and control condition.

Table 2. Continued

Mills [13]	Cross-over	14 professional male rugby union athletes (Age: 23.9 ±2.7)	Ankle	Flossband (Life Flossband) Applied flossband on both ankles (wrapped by using ankle tape method, 180 mmHg)	Pre-posttest (posttest was test after 5 minutes and after 30 minutes) All participants went through two different trials interval 7 days), one is flossbans trial, and another was control trial (without flossband) 5 minutes' warm-up exercises Flossband session: all participants were asked to seat on the floor with both knee full extension, and they did full range of ankle PF and DF (2 minutes, 2 secs/ each). Flossband was removed, and they were tested after 5 minutes and 30 minutes. Control session: all particpants did the same exercise but without wrapping flossband.	Ankle ROM, CMJ, 5-m Sprint (secs) 10-m Sprint (secs) 15-m Sprint (secs). 20-m Sprint (secs)	There was no significant differences between FLOSS and CON for any outcome measures, but there was small effect size improvement trend for CMJ performance 5minutes post and 10-m Sprint,15-m Sprint after flossband intervention.
Pisz [26]	Meta-analysis and Systematic review	4 articles were included	Ankle/calf	Flossband applied on calf/ ankle	Pre-posttest	Ankle ROM CMJ	There was a significant improvement in ankle ROM after flossband intervention, but there were insufficient evidences of flossband on jump performance.
Vogrin [16]	Crossover	19 healthy participants (14 males, 5 females, Age: 23.78 ± 4.85) Three conditions: Condition 1: low pressure Condition 2: moderate pressure Condition 3: high pressure	Thigh	Flossband Wrapped on the dominant thigh (50%, from the above the patella to below AIIS)	Pre-posttest (posttest was immediate after flossband and post 30 minutes after flossband) All participants were given three similar interventions (different degree of wrapping pressure, low, moderate and high) at three different visits (48 hours between each visit). During each visit, pre and post-test data were collected. Low pressure (< 20 mmHg) Moderate (100 – 140 mmHg) High (150 – 210 mmHg) All participants were asked to sit to the therapeutic table and did knee extension and flexion from 90 °to 0 °, 2 minutes, 3 sets, 90 secs interval.	ALSR, knee extensor and flexor MVC, TcRF(ms), TcVM(ms), TcBF (ms) DmRF(mm) DmVM(mm) DmBF(mm)	There was significant difference for the low condition between pre and posttest during the knee extensor MVC (post immediately and post 30 minutes), TcRF (post immediately) and TcVM (post 30 minutes). There was no significant difference between groups among these outcomes, but there were medium benefits between low condition and high condition (TcRF and knee extension MVC), low condition and control condition (DmRF), and high condition to control condition (DmBF).

Table 2. Continued

Vogrin [27]	Crossover	30 healthy participants (18 males, 12 females, Age: 23±4.51) Floss group: Applied on the random chosen ankle (12 right and 18 left) Control: the other ankle	Ankle	Flossband (Medical Flossing Band 1.3 mm) Standard figure 8 ankle tape method	Pre-posttest (post5 post15 post30 post45) All participants did 6 minutes' warm-up, then they did the immediate test as the baseline. Random chosen the ankle and applied the flossband, and then they were asked to do active ankle PF and DF on both ankles with knee extension sitting on bed (2 minutes/ set, 3 sets, rest 2 minutes between each set), after complete the ankle exercise, they were instructed to walk around 2 minutes. The posttest conducted after 5, 15, 30 and 45 minutes' intervention.	Active ankle PF and DF ROM,	There were significant differences between baseline and posttest (post5 post15 post30 post45) in ankle DF ROM within groups, only ankle PF ROM in flossband group.
Kielur and Powden [8]	Meta-analysis and Systematic review	6 articles were included	Ankle	Flossband Wrapped on ankle	6 studies were included (4 high qualities, 2 low quality)	Ankle DF ROM	There was moderate improvement PF ROM between pre and posttest, but there was no significant difference between floss group and control group.
Quiles-Sanchez [10]	Systematic review	9 articles were enrolled	–	–	–	Strength, endurance and function	Flossband is an effective method on strength, edurance and physical function.
Hodeaux [28]	Crossover	12 healthy elite tennis players (6 males and 6 females, age: 20.5 ±1.24) Random assign into two separate sessions (interval 24 hours)	Elbow	Voodoo Flossband (50% tension) Wrapped around elbow joint	Flossband session (pre-posttest)Applied flossband on the elbow and did 6 passive exercises within 2 minutes (3 repetation/ exercise) Control session: did the same exercises without flossband.	Passive elbow with extension and flexion ROM, forearm pronation and supination	There was no significant difference between groups during these parameters measure, but there was improvement trend for elbow ROM in flossband session comparing with without flossband session.
McCallum [29]	Experimental	30 ankle inversion participants (age: 18 to 45) Random assigned into three groups	chronic ankle inversion injury	Flossband (50% tension) Applied standard figure 8 ankle tape	Pre-posttest (5 minutes after treatment in the fourth time and 7 times) Group 1 chiropractic manipulation combined with flossband Group2: flossband (20 repetition ankle active PF AND DF within 2 minutes) Group3: chiropractic manipulation (Anterior to posterior) 7 time/ 3 weeks	WBLT, ankle PF, and DF ROM	There was a significant difference among the three groups after 4^{th} intervention and 7^{th} during EBL PF ROM and DF ROM, but there was no significant difference between the 4^{th} intervention and 7^{th} intervention and among groups.

Table 2. Continued

Maust [12]	Crossover	21 healthy active participants (8 males, 13 females, age: 22.62 ±2.99) Floss group, sham group, and control group	Thigh	Voodoo flossband (50% tension) Wrapped from above the patella and ending at the gluteal fold.	Pre-posttest Three groups did 10 bodyweight squats; 10 lunges and 20 standing hamstring curls with flossband, sham, and without flossband separately.	Hip Flexion ROM CMJ	There was significant difference among three groups in hip ROM, and there was also significant differences within flossband group and sham group in hip ROM.
Hadamus [14]	Experimental	40 healthy athletes Randomize assigned into 2 groups Floss group Control group	Thigh	Voodoo flossband (50% tension) Wrapped from above the patella to the end of gluteal fold.	Pre-posttest (posttest was tested on immediately test, 15 minutes, 30 minutes and 45 minutes) Warm-up lasts 9 minutes	Sit and reach test	There was a significant difference between the floss group and the control group after 30 minutes of intervention, however, there was an increasing trend comparing floss group to control group in different posttest.

Note: compress tissue flossing (CTF), Weight-bearing lunge test (WBLT), Counter-movement jump test (CMJ), 5-m Sprint (5-meter Sprint), 10-m Sprint (10-minutes Sprint), 15-m Sprint (15-minutes Sprint), 20-m Sprint (20-minutes Sprint)secs (seconds), CKC (closed chain), OKC (open-chain), DF (Dorsiflexion), GH (Glenhumeral), AROM (active range of motion), Wrist/Hand Disability Index (WHDI, visual analog scale (VAS), straight leg (SL), bent leg (BL), subjective tightness rating (TIGHT), instrument assisted soft tissue mobilization (IASTM), reps (repetition), week (W), anterior inferior iliac spine (AIIS), Passive range of motion (PROM), patellofemoral pain syndrome (PFPS), gastrocnemius (GS), maximal isometric voluntary plantar flexion contraction (MVC), rate of force development (RFD), straight leg raise (SLR), passive knee extension (KE), dynamic stretch (DS), passive resistive torque (PRT), Rectus Femoris muscle and Biceps Femoris muscle tensiomyography assessment (TMG), active straight leg raise test (ALSR), rectus femoris muscle contraction time (TcRF), biceps femoris muscle contraction time (TcBF), vastus medialis muscle contraction time (TcVM), rectus femoris muscle displacement (DmRF), vastus medialis muscle displacement(DmVM), biceps femoris muscle displacement (DmBF), posttest after 5, 15,30 and 45 minutes (post5 post15 post30 post45), tensiomypgraphy (TMG), Tc (gastrocnemius muscle contraction time), Dm (gastrocnemius muscle displacement).

Table 3. Flossing band application and outcomes measures

No.	Author	Country	Participant	Intervention period	Wrapping Body part	Flossband Tension	Outcome Measures							
							ROM	VAS	Muscle tightness	Strength	Squat	Muscle activity	Sprint	CMJ
1	Driller [19]	New Zealand	Healthy athletes	Acute effect	Ankle	178 ± 18 mmHg	√						√	√
2	Driller and Overmaye [15]	New Zealand	Healthy athletes	Acute effect	Ankle	178 ± 18 mmHg	√							√
3	Hagen [11]	-	Healthy college student	Acute effect	Ankle	__	√				√			
4	Kiefer [20]	USA	Healthy college student	Acute effect	Arm	50% tension	√							
5	Ross and Kandassamy [21]	UK	Heaithy participant	Acute effect	Achilles tendon	50% tension	√							
6	Stevenson [22]	USA	Patient	Acute effect	Ankle	180 mmHg	√							
7	Williams [23]	USA	Healthy participants	4 weeks	Ankle	__	√							
8	Cheatham [5]	USA	Healthy participants	Acute effect	Thigh	50% tension	√							
9	Galis and Cooper [24]	UK	Healthy participants	Acute effect	Calf	< 20 mmHg 150 mmHg 200 mmHg	√			√				
10	Garc á-Luna [7]	Spain	Patient	Acute effect	Knee	182 ± 38 mmHg		√						√
11	Kaneda [25]	Japan	Healthy participants	Acute effect	Calf	160 ± 3mmHg	√			√		√		
12	Kaneda [9]	Japan	Healthy participants	Acute effect	Thigh	__			√	√		√		
13	Konrad [17]	Austria	Healthy participants	Acute effect	Thigh	50% tension	√			√		√		√
14	Mills [13]	New Zealand	Healthy athletes	Acute effect	Ankle	180 mmHg	√						√	√
15	Vogrin [27]	Slovenia	Healthy participants	Acute effect	Thigh	Low (< 20 mmHg) Moderate (100 – 140 mmHg) High >150 mmHg			√	√		√		
16	Vogrin [16]	Slovenia	Healthy participants	Acute effect	Ankle	__	√							

Table 3. Continued

17	Hodeaux [28]	USA	Healthy athletes	Acute effect	Elbow	50% tension	√							
18	McCallum [29]	South Africa	Patients	3 weeks	Ankle	50% tension	√							
19	Quiles-Sanchez [10]	Spain	Healthy athletes	Acute effect	—	—				√				
20	Pisz [26]	Czech Republic	Healthy participants	Acute effect	—	—	√							√
21	Kielur and Powden [8]	USA	Healthy participants	Acute effect	Ankle	—	√							
22	Maust [12]	USA	Healthy participants	Acute effect	Thigh	50% tension	√							√
23	Hadamus [14]	Poland	Healthy athletes	Healthy athletes	Thigh	50% tension	√							

Note: Counter-movement jump test (CMJ), range of motion (ROM), visual analog scale (VAS).

According to the data extracted in this review, it can be assumed that the tissue flossing technique has a positive effect on joint ROM, pain, muscle tightness, muscle strength, and physical function performance (see Table 3).

3.1. The Effects of Flossing on Joint Range of Motion

Nineteen out of 23 studies examined the effectiveness of flossband application on the ROM of various joints. Fourteen out of 19 individual studies focused on comparing the effects of flossband application on ankle dorsiflexion of range of motion (DFROM) to other interventions. The findings of these 14 studies show that there was no significant difference during DFROM between the flossband group and the control group, but there was a positive trend [19,24]. However, there was a significant difference of DFROM between the pre- and post-tests in the flossband group [15,20]. Systematic evidence showed that flossband treatment is a useful method to acutely increase the effects of ankle ROM, compared to other methods [30]. Only one out of 19 individual studies wrapped flossband on the upper arm, and the results showed that shoulder flexion was significantly improved [20]. In addition, four out of 19 individual studies proved that flossband application on the thigh could improve knee flexion ROM and hip flexion ROM. Meanwhile, Cheatham, [5] pointed that flossband intervention is more effective than soft tissue mobilization or other types of instruments in the aspect of joint flexibility.

3.2. The Effects of Flossing on Pain

Only 1 out of 23 studies investigated the effectiveness of the application of flossband on chronic pain management. In García-Luna's [7] pilot study, five young male recreational athletes diagnosed with chronic patellarfemoral pain syndrome (PFPS) were recruited, and all the participants were instructed to do three counter movement jumps (CMJs) with a flossband wrapping above the patellar (with 182±38 mmHg), or without it, during pre- and post-tests for evaluation of the acute effect of variation of knee pain intensity. The results showed that the application of flossband on patients with chronic PFPS was found to significantly decrease the perception of knee pain (Analogue visual scale, VAS) after immediately removing the flossband [7]. However, there was no significant difference in a variety of pain perceptions on the affected knee between the flossband group and the control group.

3.3. The Effects of Flossing on Muscle Tightness

Two out of 23 studies examined the acute effect of flossband application on hamstring tightness by comparing the straight leg raise test (SLR). A similar flossband wrapping method, the application on the dominant thigh of healthy participants, was used in these two studies, but different interventions were compared in the aspect of effectiveness of flossband application on muscle tightness. One finding revealed that there was no significant difference in hamstring tightness among the groups (control group with a pressure of less than 20 mmHg, a moderate group with 100 mmHg to 140 mmHg, and high group with 150 mmHg to 210 mmHg), and within the groups (pre, post immediate and post 30 minutes). However, the small to medium improvement of SLR was found between the group with moderate pressure and the control group with low pressure. Small benefits were associated between the application of the flossband with the high pressure and low pressure, and there was a beneficial trend compared to the groups with low and high pressure respectively [27]. Another result showed that there was a significant difference in SLR changes after immediate removal of the flossband compared to the control group. In addition, the flossband as an effective instrument has the same benefit as dynamic stretching in reducing tightness of the hamstring, or it is even more beneficial [25].

3.4. The Effects of Flossing on Muscle Strength

Six out of 23 studies compared the acute effect of flossband application on the calf or thigh of healthy participants to improve ankle or knee strength, as well as muscle activation. Four out of 6 individual studies not only reported the effect of flossband application on strength, but it also associated on muscle activation. There was no significant difference of isometric maximal voluntary contraction (IMVC) of ankle plantar flexion force and gastrocnemius (GC) activation among the groups (group with flossband, group with static stretching, and group with resting), but the flossband application on the GC helps improve ankle dorsiflexion rate of force development for the first 100 seconds, compared to the control groups [25]. In addition, flossband application on the thigh has benefits in improving the IMVC of knee extension strength, or eccentric MVC of knee flexion, and increasing neuromuscular activity, compared to the control group [17,25,27]. Two out of 6 individual studies only mentioned flossband application on strength. In Galis' study [24], the result showed that there was no significant difference between the strength of ankle flexion and extension among the groups (control group, group with 150 mmHg flossband wrapping pressure and 200 mmHg flossband wrapping pressure), but flossband wrapping on the calf muscle with 150 mmHg might be beneficial to improve ankle dorsiflexion peak torque (DFPT), compared to the control group and the group with high wrapping pressure [24]. DFPT was improved by up to 22% after flossband application [10]. Thus, flossband seems to be beneficial to enhance muscle strength.

3.5. The Effects of Flossing on Physical Function Performance

Ten out of 23 studies examined the acute effect of flossband application on the squat, running, and jumping. Only one out of 10 individual studies compared different interventions on the performance of the body overhead weight squat. The study revealed that squat function was significantly improved after flossband application, but there was no significant difference in squat performance among the groups. Therefore, this result indicated that the flossband seems to be as effective as dynamic stretching with closed-kinematics chain or static stretching with closed-kinematics chain [11]. There are two out of 10 individual studies that compared the time of the 5-meter, 10-meter, and 15-meter sprint performance in healthy athletes between the flossband group and the control group. The results showed that there was an improvement in the 10-meter sprint and 15-meter sprint group compared to the control group, and these benefits will last up to 45 minutes [13,19,31]. Seven out of 10 studies compared the changes in jumping performance between the flossband group and the control group. Five out of 7 studies showed that there was a significant improvement in jump height, jump velocity, jump power, and jump force after applying a flossband. However, there was only an improvement trend between groups [7]. Only two studies presented that there was insufficient evidence about flossband improving jump performance [12]. Therefore, flossband could be a novel method to improve physical function.

4. Discussion

Flossband as a therapeutic intervention instrument could be used to increase ankle dorsiflexion ROM over the short term and the long term. Furthermore, small to large effect sizes have been found in previous studies. In the field of acute effects of flossband application on the ankle, Driller [19] found that flossband wrapped around the ankle significantly improved ankle dorsiflexion ROM in healthy young athletes. However, these two results were only associated with small effect sizes of 0.21 and 0.31, respectively. In the same year, Hagen's study [11] showed similar evidence about flossband significantly improving ankle dorsiflexion ROM in healthy college students (d = 0.36). In the year 2021, a systematic literature review and meta-analysis evidence discovered that ankle dorsiflexion ROM significantly increased after flossband intervention compared to the baseline, and the effect size was 0.46 [8]. At the level of equivalent evidence, only one study examined application flossband for 4 weeks, and the small effect size evidence showed that ankle dorsiflexion ROM was significantly increased after 4 weeks of intervention [23]. In contrast to the above studies, Galis and Cooper [24], Kaneda [25], and Ross and Kandassamy [21] pointed out that flossband significantly increased ankle dorsiflexion ROM with medium effect size in healthy active young participants, and the effect size was 0.77, 0.61, 0.56, respectively. Vogrin [27] also showed that flossband intervention significantly increased ankle dorsiflexion ROM with medium to large effect size in healthy young participants. McCallum's [29] study revealed that 3 weeks of applying flossband on patients with chronic ankle sprains also significantly improved ankle dorsiflexion ROM with medium effect size (d = 0.76). The varying results on different levels of improvement after flossband application were due to the amount of tension or wrapping pressure and wrappling methods in these studies. Around 50% tension of flossband or 150 mmHg wrapping pressure could improve ankle dorsiflexion ROM more than the other types of wrapping tension and pressure. In Galis and Cooper's [24] study, the researcher found that applying 150 mmHg wrapping pressure on the ankle could significantly increase dorsiflexion ROM compare to 200 mmHg wrapping pressure and low wrapping pressure. Kaneda [25], Ross and Kandassamy [21], and McCallum [29] also pointed out that 160 $\pm$ 3 mmHg or 50% tension could improve ROM with medium effect size compared with the other studies which used high pressure or stretch tension. Meanwhile, the variance of flossband application on different parts of the human body could be another factor that led to the differing results. Therefore, 50% tension of flossband or 150 mmHg wrapping pressure could be a generalization for the other joints and more research about the long-term effects of flossband should be conducted in future studies.

Flossband application is not only beneficial to improve ankle ROM, but has also been proven to increase the ROM of other joints. Kiefer assessed the effect of flossband on the shoulder joint of healthy college students, and the results showed that the acute intervention significantly increased shoulder flexion ROM [20]. Hadamus [14] concluded that trunk flexibility was also significantly improved after using flossband as a warm-up assistant tool compared to the control group. Knee flexion ROM was significantly improved after flossband application, but this improvement only had a small effect size (d = 0.47) [5]. Maustk found that flossband can be used to increase hip flexion when compared with to sham group or control group [12], but Konrad [17] mentioned that flossband may not be used to increase hip flexion. Hodeaux [28] pointed out that there was no significance for elbow flexion ROM between the flossband group and control group, but there was an improvement trend with small effect size (d = 0.32). By reviewing the studies of Hodeaux [28] and Konrad [17], small sample size may be one of the factors which led to a significant effect. Therefore, future studies should aim to recruit a bigger sample size. In addition, it is worth noting that most studies were focused on applying flossband on the ankle joint, especially on healthy athletes or active young people rather than patients. Therefore, there was less evidence showing the effects of flossband on the patients as well as the effect of flossband application on other body parts or joints. Thus, more related evidences should be sought after in future studies.

Flossband seems to act as an effective pain management tool by producing shear force on myofascia, increasing joint space, and improving blood circulation. That said, there was only one article reporting the application of flossband on knee pain patients. After flossband application, perceived pain in the knee was significantly reduced, and this study showed a big effect size [7]. Interestingly, the available evidence of flossband on pain management was scarce. Thus, more studies about the effect of flossband application for pain management of different etiologies should be conducted in the future.

Flossband might be used into reducing muscle tightness, thus, flossband could be a potentially therapeutic tool for injury prevention and rehabilitation of the skeletal muscular fascial system disease. Applying flossband on the hamstring significantly changed its function, especially increasing hamstring flexibility. There were only two studies on muscle flexibility changes after applying flossband on soft tissues. All the participants were asked to do active knee flexion and knee extension exercises in 2 minutes by wrapping flossband on the hamstring, and the small to medium effect size evidence showed that straight leg raise test was improved after removing the flossband compared to the control group with moderate pressure of flossband application [27]. Kaneda [25] also supported that flossband wrapping around hamstring muscles from above the knee significantly enhanced straight leg raise performance compared to the group without flossband. The mechanism behind the muscle flexibility changes caused by flossband may be due to shear force during tissue flossing or the thermal effect during flossing. However, the exact physiological mechanism of flossband has not been examined. In the future, more studies about the effects of flossband on skeletal muscular fascial system and its physiological mechanism needs to be conducted.

Flossband is beneficial to enhance muscle strength, but there was controversial evidence of increasing muscle activity. Galis and Cooper [24] highlighted that nearly 150 mmHg of flossband wrapping pressure was possibly beneficial to improve ankle dorsiflexion peak torque after applying flossband on the calf muscles (d = 0.27). However, over wrapping pressure was observed to impair ankle dorsiflexion peak torque ability (Galis & Cooper, 2020). It can be seen that appropriate wrapping pressure may be an important factor affecting strength. Research finding showed that flossband wrapping around calf muscles significantly improved isometric maximal voluntary contraction (MVC) of ankle plantar flexion force at the end of plantar flexion (d = 0.27) and enhanced rate of force development within 0-50ms (d = 0.38). Meanwhile, there was a trend to activate calf muscles (d = 0.47) [9]. In contrast, evidence from a tensiomyography perspective showed that ankle flossband application on gastrocnemius muscle contraction time was not obvious [27]. The other evidences showed that applying flossband around the thigh improved eccentric MVC of the knee extension force (d = 0.59), flexion force (d = 0.56) and knee extension passive torque at the end of knee extension (d = 0.73) [25]. Konrad mentioned that wrapping flossband around the thigh significantly improved MVC of knee extension compared to the control group (d = 0.77), but leg muscle activation was not found in this study [32]. Vogrin [16] and Vogrin [27] pointed out that wrapping flossband around the thigh provided small to medium benefits to improve isometric MVC of knee extension force compared to the control group, and it significantly increased isometric MVC of knee extension and rectus femoris muscle contraction time after flossing. The underlying physiological mechanisms of flossband on the aspect of force production and muscle activation have yet to be determined, but available evidences showed that there are several viewpoints of using flossband to improve force production mechanism as well as improve neuromuscular function. Flossband could facilitate fascial layers sliding or arrange the disordered fascial tissue. The smooth sliding between the layers of fluid fascia could mediate local muscle contraction or elongation as well as restoration of muscle length for optimum myosin head coupling mechanism [33]. The heat from intramuscular friction would be another important factor which could impact muscle contraction strength [9]. Soft tissue flossing with compression also is a critical factor which directed neuromuscular control of coordination and movement [33]. Some studies even suggested that tissue flossing might promote the release of growth hormones and norepinephrine level following the compression [32]. Flossband wrapping on the soft tissue indeed increased muscle strength and enhanced rate of force development, but it seemed to be not present in neuromuscular muscle activation. Therefore, essential evidence by using surface EMG evidence, ultrasound image evidence and physiological evidence on the level of neurological function after flossing needs to be investigated in the future.

Human functional movement quality can be improved through the tissue flossing technique. Flossband wrapping around ankle significantly improved squat performance when compared to pre-test performance, and it provided medium effect size benefits [11]. Small effect size evidence showed that wrapping flossband around the ankle could be beneficial for sprint performance and vertical jump ability compared to the control group [19]. Another evidence supported that there was small effect size enhancement in jump height and jump velocity between the flossband group and control group, and there was significant improvement in jump height after flossing [19]. Applying flossband on the knee pain patients also improved jump performance. This result was consistent with the previous findings, but the difference was that it also improved jump velocity, jump power, jump force and jump time in this study. Therefore, the use of flossband on patients led to obvious improvements in jumping performance [7]. Knorad [32] showed that flossband wrapping around the thigh could not increase the vertical jump height, and he also pointed out that flossband application on the thigh in healthy participants was not enough to induce significant changes in jump height because jumping is a complex function movement which is related to several muscle groups. Milles [13] found that applying flossband on the highly treated ruby athletes had less potential to improve jump performance and sprint performance. However, a meta-analyses evidence confirmed that there was a positive impact of flossing on jump performance [26]. Available evidence showed that the effects of flossband could lead to noticeable improvement in the general population or patients. Thus, more studies on different populations should be done in the future.

5. Conclusions

Flossband as a novel and emerging therapeutic tool has been used in sport as well as clinical practice in recent years. Based on the findings in previous studies, flossband wrapping on different soft tissues or peripheral joints could be a valid method to increase joint ROM, manage pain, and reduce muscle tightness. Not only that, it could also have other potential benefits and enhance muscle strength, exert higher rate of force development in per unit time, as well as improve physical functional performance such as squat, sprint and jump ability. In addition, the key to apply this technique is mastering the wrapping tension and pressure. Specifically, 50% flossing tension or approximately 150 mmHg wrapping pressure could lead to positive effects on the outcomes of ROM, pain, muscle stiffness, muscle strength and physical function performance when compared with low or high tension or pressure. Therefore, the above findings indicate that flossband is a useful treatment option, and it can provide significant contribution in the field of athletic training, sports injury prevention and rehabilitation in the future.

6. Perspective for Future Research

Based on the previous studies, limited evidences showed that flossband as a novel technique provided small to medium effect size benefits in the aspects of increasing ROM, strengthening muscle force, releasing muscle tension and improving physical functional performance. Additionally, it showed a high effect size for pain management. Unfortunately, these evidences of flossband mostly involved soft tissues and joints of the limbs, and none of studies examined the effects on trunk function or evaluated its specific physiological mechanism. Therefore, it would be pertinent for future studies to broaden the field of flossband application and further investigate its physiological mechanism. In addition, most studies were mainly conducted on a population of healthy and active participants or well-trained athletes, and very little research has been done with patients. At the same time, those studies only investigated the short-term effects rather than the long-term effects of flossband application on different soft tissues or peripheral joints. Therefore, more studies about the effects of flossband application with patients should be implemented in the future, especially with regards to the long-term effects of flossband application.

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