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Short-term and long-term effects of ankle joint taping and bandaging on balance, proprioception and vertical jump among volleyball players with chronic ankle instability☆

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ABSTRACT

Objective: This study hypothesized that the prolonged use of taping during athletic activities produces more significant increases in proprioception, balance, and vertical jump among volleyball players with CAI.
Design: A randomized controlled study.
Participants: One-hundred participants with chronic ankle instability (CAI) participated in this study. Participants were distributed into 3-groups: taping group, bandaging group, and control group.
Primary outcome measures: Proprioception (ankle range of motion absolute error), balance(Y-balance test), and vertical jump (vertical jump tester).
Interventions: Three interventions were performed: ankle rigid taping, ankle bandaging, and placebo taping. The measurements were performed at baseline, immediately, 2-weeks and 2-months after support.
Results: Immediately after supports, there were non-significant differences between all groups for proprioception, balance ($P < .05$). There was a significant difference between banding and control groups, and taping and control groups for the vertical jump ($P < .05$). After 2-weeks and 2-months, there were significant differences between bandaging and control groups, and taping and control groups for proprioception, balance, and vertical jump ($P < .05$). There were non-significant differences between taping and bandaging groups ($P < .05$) during all assessments.
Conclusion: This study indicated that ankle taping and bandaging immediately improve vertical jump only; while they improve proprioception, balance, and vertical jump after 2-weeks and 2-months.

1. Introduction

Ankle sprains are one of the most frequent injuries which occur among both athletes and normal individuals (Chinn & Hertel, 2010; Fong et al., 2007). A large scale systematic review reported that ankle sprains account for about 80% of injuries occur among athletes in almost sports (Fong et al., 2007). Ankle sprains are the most common injury among volleyball players accounting for about 41% of all volleyball associated-injuries (Verhagen et al., 2004). Approximately, 20% of acute ankle sprains turn to chronic ones. Chronic ankle sprains cause severe proprioceptive dysfunctions, such as a joint position-sense deficit and delayed peroneal muscle-reaction time, which cause a significant ankle instability and balance deficit (Jay Hertel, 2000). Thus, any balance training program for patients with chronic ankle instability (CAI) should include ankle proprioceptive training as a major component(Conti et al., 2008; Lim & Tan, 2009).

The rehabilitative professionals strongly recommend using ankle taping as a powerful proprioceptive training for improving proprioception and balance in patients with CAI. Ankle taping helps in adjusting the abnormal excessive movements that occur during sports such as excessive ankle plantarflexion or excessive varus stress. Also, ankle taping improves the firing rate of cutaneous

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mechanoreceptors which helps in better proprioceptive feedback and better balance control and ankle function (Cordova et al., 2005).

In the literature, there are high contradictions among the results of conducted studies which helped in producing no concise conclusions on its effectiveness (Bunton et al., 1993; Hadadi & Abbasi, 2019; Partin et al., 1994). Some studies have demonstrated that ankle joint taping significantly improves the perceived stability, static and dynamic balance control, and functional performance but not postural control among individuals with CAI after 7 days (Alguacil-diego et al., 2015; De-La-Torre-Domingo et al., 2015; Cline et al., 2018; Gehrke et al., 2018). On the other side, other studies have demonstrated that ankle joint taping has non-significant effects on ankle functional instability, functional performance, static and dynamic balance control, or reaching distance among individuals with CIA (Bicici et al., 2012; Delahunt et al., 2010; Halim-Kertanegara et al., 2017; Hettle, 2013).

Furthermore, these ankle taping studies have moderate methodological quality with a limited level of evidence (Fousekis et al., 2017); this might be attributed to that these studies have only focused on the immediate effects of taping on balance and function with including a small number of participants. In the literature, there is a strong recommendation on conducting long-term large randomized controlled trials to overcome these limitations (Hadadi & Abbasi, 2019). Thus, this study hypothesized that the prolonged use of taping during athletic activities produces more significant increases in proprioception, balance, and vertical jump among volleyball players with CAI.

2. Materials and methods

2.1. Design

A single-blinded randomized controlled design was used, in which the participants were blinded to the study procedures. All participants were asked to deeply read the study procedures and sign a detailed consent form before starting study procedures. This study was conducted in the physical therapy and rehabilitation laboratories at Istanbul Gelisim University, Turkey. This study was approved by the ethical committee of Istanbul Gelisim University. The registration number of this study protocol is NCT04377269.

2.2. Sample size calculation

A priori power test was applied to calculate the suitable sample size for this study. The G*POWER software (ver. 3.1.9.2, Heinrich-Heine-University, Düsseldorf, Germany) was used to calculate the suitable sample size for the MANOVA test using 3 groups, a power level of 80%, a significance level of 5%, nine measurements and medium effect size (dz = 0.25) (Faul et al., 2007). Grounded on the above-mentioned assumptions, the sample size needed for this study was 95 patients. We added 18 subjects to compensate for any dropout. A minimum power of 80% or more should be used because it is acceptable in most studies (Kadam & Bhalerao, 2010).

2.2.1. Participants' recruitment

One-hundred and thirty volleyball players with CAI, age range from 18 to 30 years-old were initially examined. Participants were recruited from the Turkish national sports clubs. The participants were excluded if they report previous hip/pelvis, knee, or foot surgery within the past year, leg length discrepancies, have known balance impairment due to neurological disorders, vestibular disorders, pregnancy, brain concussion within the previous three months, or taking any medications that may affect alertness or balance. Thirty participants were excluded from this study. Seventeen participants of them did not meet the selection criteria, eight participants participated in the baseline assessment and did not attend any post-tests assessments, and five participants did not attend two-week or two-month assessments.

Participants were divided randomly into three groups (Taping group n = 33), (Bandaging group n = 33), and (Placebo taping (control) group n = 34). The randomization process was conducted by a college staff who did not join this study, using a dice simple randomization method. Every two numbers on the dice represented a group: 1 and 4 = Taping group, 2 and 5 = Bandaging group, and 3 and 6 = Control group. All included participants were diagnosed with CAI. Chronic ankle instability was determined if the participant had at least two acute ankle sprains during the past 6 months and it is accompanied by swelling, pain, and history of multiple episodes of the ankle giving way (Someeh et al., 2015). A diagram of the patients' flow through the study is shown in Fig. 1.

2.3. Evaluative procedures

The primary outcome measures were proprioception, balance, and vertical jump. In the beginning, leg length was measured (right and left) while the participant was supine, from the anterior superior iliac spine to the inferior border of the ipsilateral medial malleoli, using a standard measure tape. The dominant leg was determined according to Vauhnik. & ark, modified version (Vauhnik et al., 2008) who reported that the dominant leg should be used in at least 2 of the 3 following activities: 1) Kicking a ball, 2) Drawing a diamond figure on the ground, and 3) Using the leg to step over a spider toy, was considered as the dominant leg(Vauhnik et al., 2008). After this, the assessment procedures (Proprioception, balance, and vertical jump) were taken. All measurements were taken four times: before applying the external supports (taping, bandaging, and placebo taping) and considered as baseline measurements, immediately after applying the external supports, two weeks after applying the external supports, and two months after removing the external support.

2.4. Proprioception measurement

The measurement of proprioception followed the study conducted by Miralles et al., (Miralles et al., 2016). Initially, The procedures were explained to each participant before starting measurements. The proprioception measurements were performed through three steps. In the first step, the participant was seated on a chair with back-support with feet touching the ground surface, and they asked to close their eyes. The participant's ankle was assessed in 4 different positions (10° dorsiflexion, neutral position, 10° plantarflexion, and 20° plantarflexion). Each position was applied for just one time and held for 5 s, using two different custom-made wood slopes, each sloop designed to be at a certain angle (10° and 20°). The participants were asked to remember these positions because they must do it later by themselves (Iris et al., 2010). In the second step, the participants were asked to walk freely beside the therapist for 10 min with eyes closed. In the third step, the participants were asked to sit on a higher chair with feet off the floor while keeping eyes closed. The participants were asked to do the previously learned ankle positions (10° dorsiflexion, neutral position, 10° plantarflexion, and 20° plantarflexion), respectively (Iris et al., 2010). The ankle ROMs for these positions were measured using a universal goniometer, which has a high validity and reliability IC: 0.82 to 0.96 (Menadue et al., 2006). The absolute error was calculated by subtracting the performed ROM from the previously learned ROM. Then the absolute error was recorded and used in the statistical analysis. The use of the absolute error in measuring the proprioception is a reliable and validated measure 8 with an

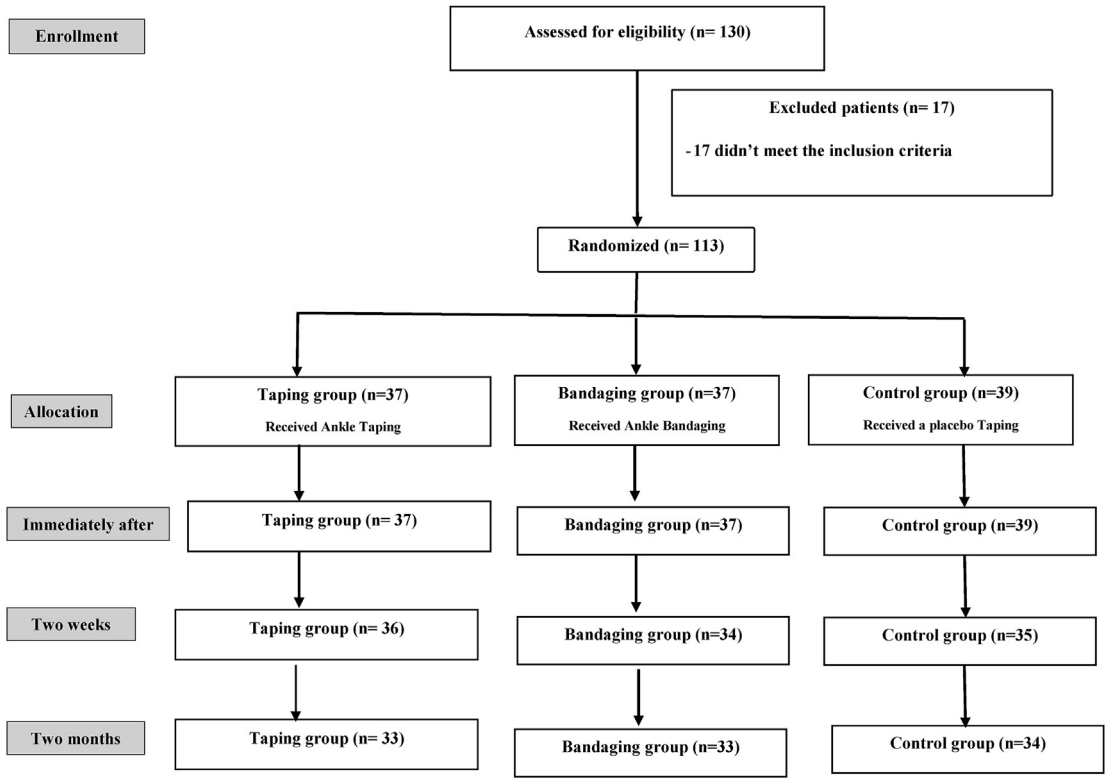

Fig. 1. Patients flow chart.

excellent intraclass correlation coefficient (ICCs) ranging from 0.79 to 0.95 (Deshpande et al., 2003). The custom-made wooden sloops are shown in Fig. 2.

2.5. Balance measurement

The Y-Balance test was used to evaluate balance (Bulow et al., 2019). Eight strips of an adhesive tape with a 6 feet length were used. Two signs were plotted on the surface by using these strips ('+' and 'x' signs), both signs intersected to form a star shape with a 45° angle between every two strips. Then, the strips of all directions were removed and just three directions remained (anterior (A), posteromedial (PM), and posterolateral (PL) directions). The participants were asked to wear sports clothes and sports shoes while stepping on the center of the star using the affected leg. the participants were asked to maintain the plantar aspect of the first metatarsophalangeal joint (ball of the foot) on the center of the star shape to maintain consistency of foot placement. The participants were asked to reach on each of the three strips as far as possible with the non-affected leg to make a light touch on each line and return the reaching leg to the center while maintaining a single-leg stance with the affected leg in the center of the star. Each participant started the test from the anterior direction and progressed in a clockwise direction. During the posterolateral direction reaching tasks, the participants were asked to reach behind the stance leg to complete the task (Hadadi et al., 2014).

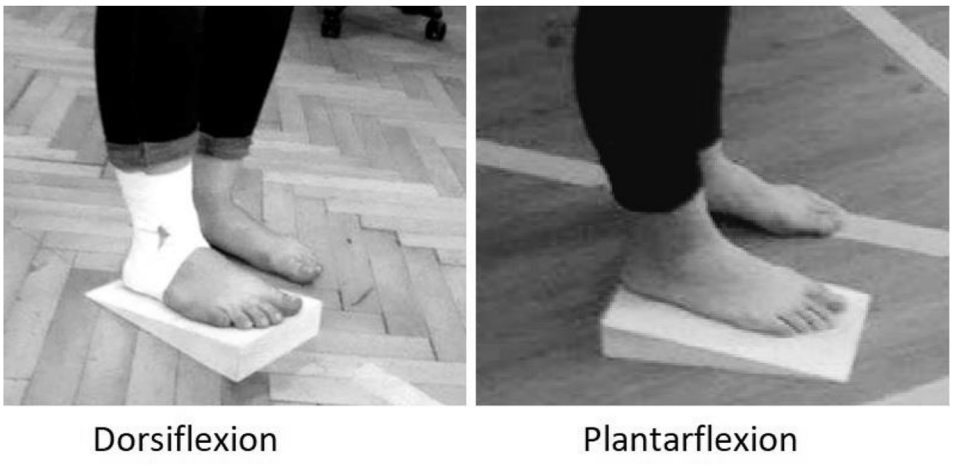

Fig. 2. Custom - made wooden sloops.

Before starting the measurement procedures, participants were asked to practice 6 attempts to reduce the learning-error effect. The participants were asked to perform 3 trials in each of the three directions with a 5-min rest period taken between each one of these three trials. The therapist measured the reaching distance (The distance between the gird center to the participant's maximal reaching point) using a standard tape measure. If the participant used the swing leg for a high amount of support (unable to maintain balance on the stance leg) or removed the stance leg from the center any time while doing the trial, the attempt was canceled and repeated. In the case of rejecting trial, verbal feedback was given to participants to avoid this error(s) before the next trial (Hadadi et al., 2014). The average of the three trials was calculated using this formula ((trial #1 + trial #2 + trial #3)/3). Then the average of the three normalized trials of leg length was calculated by this formula ((average distance in reaching direction/leg length) × 100). This normalized reaching distance was used in the statistical analysis.

2.6. Vertical jump height measurements

The vertical jump tester (Sports Imports, Columbus, OH) (Wikstrom et al., 2006) was used to measure the vertical jump height. The test was done through two steps. Firstly, the participants were asked to stand beside the vertical jump tester and try to reach up the highest possible point using his preferred or dominant hand; while they stood on feet (double-leg stance on toes). Secondly, the participants were asked to perform a counter-movement jump and try to touch the highest possible point using his preferred or dominant hand. The reaching distance which the participant reached in each step was recorded (Wikstrom et al., 2004; Wikstrom, Tillman, & Borsa, 2005; Wikstrom, Tillman, Smith, & Borsa, 2005).

2.7. Treatment procedures

Three ankle joint external supports were used in this study**,** taping, bandaging, and placebo taping**.** These ankle joint external supports were applied during usual athletic training activity sessions. The athletic training session lasts 2–3 h/session for 3–5 training sessions/week. At each assessment session (every two weeks), the external ankle support (tape, bandage, and placebo tape) was removed and replaced by a new one.

2.8. Ankle taping

In this study, a hard preventive Zinc oxide tape was used (Iris et al., 2010). Before taping, some preparation procedures were performed. The participants were asked to wash their feet with water and soap, then they had to dry it well. Non-adhesive gauze pads were applied before taping on the front and back of the ankle to prevent blisters. Then a pre-wrap adhesive tape was wrapped starting from the arch of the foot and going up to the bottom of the calf muscle. The taping procedures consisted of three separate steps. The first step included the application of the anchor tape. The anchor tape was applied by wrapping the tape circumferentially just above the malleolar level at the lower end of the shank. The second step included the application of the stirrup tape. The stirrup tape was performed two times by holding the foot in a neutral position and the tape is placed as it passed through the medial side of the ankle (under the foot), just over the heel area (posterior one-third of the foot) and up along the lateral side of the ankle. The third step included the firm attachment of the ends of the stirrups to the anchor tape which applied during the first step and this attachment was reinforced with a locking tape during the third and final step by once again applying the tape circumferentially just above the malleolar level at the lower end of the shank. The taping procedures were applied by an experienced physical therapist according to the health association requirements (Iris et al., 2010). Then, the participants were instructed to wear their sports shoes over the tap.

2.9. Ankle placebo taping

The tape type used in this group was the same tape used in the taping group using the same preparation procedures, non-adhesive gauze pads, and pre-wrap adhesive tape but tapping procedures were different. A 4 inches long tape was applied on the lateral side of the leg, just above the lateral malleolus, and aligned with peroneus longus tendon. Participants were informed that this type of taping will support the ankle joint and decrease the ankle injuries by increasing the joint position sense, thus will increase their performance (Sawkins et al., 2007).

2.10. Ankle bandaging

In this study, a standard 4 inches width elastic bandage was used. Before bandaging the participants were asked to wash their feet with water and soap, then they had to dry it well. Then the elastic bandage was wrapped around the ankle joint in the form of an 8-figure shape. The bandage started from the forefoot, moved diagonally upward with a steep enough to go above the heel and it ended around the lower calf area to form an anchor. Then, it moved diagonally down across the mid-foot, again wrapped around the forefoot, and went diagonally up to finish off around the lower calf, leaving the heel open (Fousekis et al., 2017). The participants were instructed to wear their sports shoes over the bandage.

2.11. Statistical analysis

Participants' files were coded by a faculty administrator who did not involve in this study. The data analysis trailed the intention-to-treat analysis, and general linear models of multivariate of analysis for repeated measurements (MNOVA) test was used to calculate the treatment-time interaction in every group, whereas independent MANOVA test was used to calculate the treatment-time interactions between groups. The outcome measures were taken at the baseline, two weeks, and two months. The mean and standard deviation were calculated for every dependent variable. In this study, the baseline characteristics of participants in the intervention and control groups were compared using Pearson chi-squared tests for categorical variables, involving gender, previous pain history, and diabetic history. A *t*-test was used for the continuous variables of leg length (inches), playing years. The significance level was established at $P < .05$ SPSS (ver. 25, IBM Inc., Armonk, NY, USA) was utilized for the statistical analysis in this study.

3. Results

At the baseline, there were non-significant differences between the groups in age, height, leg length, weight, BMI, and playing years, as $P > .05$. The measurement records of ankle joint ROM, Vertical jump, and reaching distance, were normally distributed in both groups (Shapiro-Wilk test, $P > .05$)(Rochon et al., 2012). The demographic and physical characteristics of participants at the baseline are shown in Table 1.

Within-group comparisons showed that there were non-significant changes in the absolute error, and the normalized reaching distances, immediately after using the external supports in all groups in comparison to the baseline measurements as ($P > .05$). While after 2-weeks and after 2-months, the absolute error significantly decreased, and the normalized reaching

Table 1
Physical characteristics of patients in all groups.

Items	Taping group	Bandaging group	Placebo group	P
	Mean ± SD	Mean ± SD	Mean ± SD	
Age (yrs.)	22.25 ± 2.96	23.56 ± 4.25	22.95 ± 3.24	>0.05
BMI	23.25 ± 1.01	24.30 ± 1.11	23.89 ± 1.85	>0.05
Male	18	19f	19	>0.05
Female	15	14	15	>0.05
Leg Length (inches)	37.15 ± 1.78	36.26 ± 2.13	36.84 ± 2.05	>0.05
Playing years (yrs)	8.54 ± 1.65	9.11 ± 2.41	8.97 ± 3.56	>0.05
Smoking	3	2	5	>0.05
Non-smoking	30	31	29	>0.05

SD: standard deviation, P: probability, yrs: years. *: significant.

distances significantly increased in all groups in comparison to the baseline measurements as (P < .05). Vertical jump hight showed a significant increase immediately after using the external supports, after 2-weeks, and after 2-month in all groups in comparison to the baseline measurements (P < .05). Within-group, comparisons for the taping, bandaging, and control groups are shown in Tables 2, 4 and 6.

The comparisons between taping and control groups showed that there were non-significant differences in the standard error values, and normalized reaching distance at baseline measurements and immediately after taping as (P > .05). While after 2-weeks and 2-months, there was a significant decrease in the standard error values, and a significant increase in the normalized reaching distance in taping group as (P < .05).

The comparisons between bandaging and control groups showed that there were non-significant differences in the standard error values and the normalized reaching distance at baseline measurements and immediately after taping as (P > .05). While after 2-weeks and 2-months, there was a significant decrease in the standard error values, and a significant increase in the normalized reaching distance in bandaging group as (P < .05).

The taping and the bandaging groups when compared to the control groups showed a non-significant difference in the vertical jumping height at the baseline measurements (P > .05). While there was a significant increase in the vertical jump height in both taping and bandaging groups immediately after taping, after 2-weeks, and after 2-months as (P < .05).

The comparison between taping and bandaging groups showed non-significant differences in absolute error values, reaching distance, and vertical jump height at the baseline measurements, immediately after taping and bandaging, after 2-weeks, and after 2-months. Between-groups comparisons are shown in Tables 3–5 and 7, and Figs. 3–5.

4. Discussion

This study investigated the short-term and the long-term effects of two types of external supports (particularly rigid taping) on ankle proprioception, balance control, and vertical jump. This study is unique as it is the first study that demonstrated the long-term effects of taping on these previous measurements.

Table 2
Repeated measure ANOVA of proprioception (ROM standard Error) between the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support	Immediately after support			2 weeks after support			2 months after support		
		M±SD	M±SD	95%CI	P	M±SD	95%CI	P	M±SD	95%CI	P
10° dorsiflexion	Tape	5.88 ± 1.05	5.56 ± 1.00	.27–.87	>.05	4.12 ± 1.02	1.27–2.26	<.01*	3.06 ± .75	2.37–3.27	<.01*
	Bandage	5.85 ± 1.00	5.61 ± 1.27	.37–.86	>.05	4.18 ± 1.58	1.09–2.24	<.01*	3.09 ± .91	2.29–3.23	<.01*
	Control	5.59 ± 10.13	5.12 ± 0.81	.39–.98	>.05	5.06 ± 1.07	.07–.99	<.01*	4.18 ± 1.29	.85–1.98	<.01*
Neutral position	Tape	3.94 ± .97	3.61 ± 1.00	.11–.77	>.05	2.10 ± .84	1.40–2.29	<.01*	1.61 ± .97	1.87–2.80	<.01*
	Bandage	4.03 ± .88	3.79 ± .86	.23–.71	>.05	2.15 ± .71	1.45–2.31	<.01*	1.64 ± .70	2.01–2.78	<.01*
	Control	3.88 ± 1.45	3.38 ± 1.10	.19–1.19	>.05	3.12 ± .84	.21–1.32	<.01*	2.85 ± .66	.46–1.60	<.01*
10° plantarflexion	Tape	4.82 ± .92	4.52 ± .97	.12–72	>.05	2.88 ± .86	1.51–2.37	<.01*	1.82 ± .81	2.57–3.43	<.01*
	Bandage	4.94 ± .93	4.61 ± 1.37	.24–.91	>.05	2.76 ± .75	1.77–2.59	<.01*	1.91 ± 1.16	2.53–3.54	<.01*
	Control	4.53 ± .96	4.12 ± .98	.02–.84	>.05	3.91 ± 1.08	.12–1.12	<.01*	3.53 ± .83	.53–1.47	<.01*
20° plantarflexion	Tape	6.30 ± .95	6.33 ± 1.02	.48–.54	>.05	4.00 ± 1.37	1.79–2.82	<.01*	3.46 ± 1.60	2.08–3.62	<.01*
	Bandage	6.49 ± 1.18	6.09 ± 1.94	.39–1.18	>.05	4.03 ± 1.05	1.85–3.06	<.01*	3.52 ± 1.15	2.48–3.46	<.01*
	Control	6.03 ± 1.22	6.00 ± .92	.53–.59	>.05	5.32 ± 1.98	.03–1.44	<.01*	4.97 ± 1.92	.25–1.87	<.01*

M: Mean, SD: Standard deviation, CI: Confidence interval, P: Probability, *: Significant.

Table 3
Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support			Immediately after support			2 weeks after support			2 months after support		
		MD ± SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P
10° dorsiflexion (degree)	Control vs Tape	.29 ± .26	.23–.81	>.05	.46 ± .26	.05–.96	>.05	.94 ± .27	.41–1.46	<.02*	1.16 ± .25	.63–1.61	<.01*
	Control vs Bandage	.26 ± .26	.26–.78	>.05	.49 ± .26	.02–.99	>.05	.88 ± .27	.35–1.40	<.02*	1.09 ± .25	.59–1.58	<.01*
	Tape vs Bandage	.03 ± .26	.49–.55	>.05	.03 ± .26	.48–.54	>.05	.06 ± .27	.47–.59	>.05	.03 ± .25	.47–.53	>.05
Neutral position (degree)	Control vs Tape	.06 ± .28	.49–.61	>.05	.22 ± .24	.26–.71	>.05	1.03 ± .20	.64–1.42	<.01*	1.25 ± .19	.87–1.63	<.01*
	Control vs Bandage	.15 ± .28	.40–.70	>.05	.41 ± .24	.08–.89	>.05	.97 ± .20	.58–1.36	<.01*	1.22 ± .19	.84–1.60	<.01*
	Tape vs Bandage	.09 ± .28	.46–.64	>.05	.18 ± .24	.30–.67	>.05	.06 ± .20	.33–.45	>.05	.03 ± .19	.35–.41	>.05
10° plantarflexion (degree)	Control vs Tape	.29 ± .23	.17–.74	>.05	.40 ± .27	.15–.94	>.05	1.03 ± .22	.59–1.47	<.01*	1.71 ± .23	1.25–2.17	<.01*
	Control vs Bandage	.41 ± .23	.05–.87	>.05	.49 ± .27	.06–1.03	>.05	1.15 ± .22	.71–1.60	<.01*	1.62 ± .23	1.16–2.08	<.01*
	Tape vs Bandage	.12 ± .23	.34–.58	>.05	.09 ± .28	.46–.69	>.05	.12 ± .22	.32–.57	>.05	.09 ± .23	.37–.55	>.05
20° plantarflexion (degree)	Control vs Tape	.27 ± .27	.27–.82	>.05	.33 ± .34	.33–1.00	>.05	1.32 ± .37	.59–2.06	<.02*	1.52 ± .39	.75–2.29	<.01*
	Control vs Bandage	.46 ± .27	.09–.100	>.05	.09 ± .34	.57–.76	>.05	1.29 ± .37	.56–2.03	<.02*	1.46 ± .39	.68–2.23	<.01*
	Tape vs Bandage	.18 ± .28	.37–.79	>.05	.24 ± .34	.43–.91	>.05	.03 ± .37	.71–.77	>.05	.06 ± .39	.72–.84	>.05

MD: Mean difference, SD: Standard error, CI: Confidence interval, P: Probability, *: Significant.

Table 4
Repeated ANOVA of balance between' the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support	Immediately after support			2 weeks after support			2 months after support		
		M±SD	M±SD	95%CI	P	M±SD	95%CI	P	M±SD	95%CI	P
Anterior (inches)	Tape	39.46 ± 1.13	40.23 ± 1.99	.64–1.59	>.05	41.31 ± .64	1.09–2.72	<.01*	43.07 ± 1.85	2.75–4.46	<.01*
	Bandage	39.88 ± .68	40.06 ± 1.18	.31–0.69	>.05	41.96 ± 1.08	1.62–2.56	<.01*	42.73 ± 1.00	2.44–3.27	<.01*
	Control	39.79 ± .78	40.10 ± .74	.04–0.65	>.05	40.40 ± .80	.32–.90	<.01*	40.95 ± .73	.91–1.41	<.01*
Posteromedial (inches)	Tape	54.67 ± .87	55.01 ± 1.68	.36–1.03	>.05	56.95 ± 1.60	1.73–2.81	<.01*	57.35 ± .91	2.34–3.01	<.01*
	Bandage	54.55 ± .78	54.91 ± 1.05	.80–.92	>.05	57.36 ± .80	2.44–3.18	<.01*	57.68 ± .82	2.76–3.50	<.01*
	Control	54.36 ± .89	54.95 ± 1.09	.05–.90	>.05	55.49 ± 1.03	.65–1.61	<.01*	55.89 ± 1.06	1.11–1.95	<.01*
Posterolateral (inches)	Tape	53.40 ± .88	53.87 ± 1.77	.25–1.19	>.05	55.61 ± 1.01	1.83–2.60	<.01*	55.71 ± 1.10	1.92–2.71	<.01*
	Bandage	53.59 ± .74	53.95 ± .83	.21–.75	>.05	55.95 ± 1.30	1.89–2.84	<.01*	56.22 ± 1.37	2.10–3.16	<.01*
	Control	53.42 ± .90	52.83 ± .97	.05–.86	>.05	54.25 ± 1.26	.43–1.23	<.01*	54.25 ± 1.13	.37–1.28	<.01*
Composite score	Tape	49.18 ± .67	49.85 ± 1.83	.41–1.39	>.05	52.85 ± .92	3.30–4.06	<.01*	53.08 ± .95	3.21–4.30	<.01*
	Bandage	49.34 ± .51	49.83 ± 1.38	.01–1.00	>.05	52.52 ± .66	2.90–3.46	<.01*	52.77 ± .52	3.17–3.68	<.01*
	Control	49.19 ± .64	49.41 ± .66	.11–.60	>.05	50.05 ± .83	.60–1.11	<.01*	50.36 ± .70	.93–1.42	<.01*

M: Mean, SD: Standard deviation, CI: Confidence interval, P: Probability, *: Significant.

Table 5
Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support			Immediately after support			2 weeks after support			2 months after support		
		MD ± SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P
Anterior (inches)	Control vs Tape	.33 ± .22	.76–.10	>.05	.13 ± .34	.55–.81	>.05	.98 ± .33	.32–1.63	<.05*	2.12 ± .31	1.50–2.74	<.05*
	Control vs Bandage	.08 ± .22	.35–.51	>.05	.03 ± .34	.64–.71	>.05	1.56 ± .33	.91–2.22	<.01*	1.78 ± .31	1.16–2.40	<.01*
	Tape vs Bandage	.41 ± .22	.02–.84	>.05	.16 ± .34	.52–.85	>.05	.59 ± .33	.07–1.25	>.05	.34 ± .32	.29–.97	>.05
Posteromedial (inches)	Control vs Tape	.32 ± .21	.73–.10	>.05	.33 ± .32	.30–.96	>.05	1.46 ± .29	.88–2.04	<.01*	1.46 ± .23	1.01–1.92	<.01*
	Control vs Bandage	.20 ± .21	.22–.61	>.05	.23 ± .32	.40–.86	>.05	1.88 ± .29	1.30–2.45	<.01*	1.79 ± .23	1.34–2.25	<.01*
	Tape vs Bandage	.12 ± .21	.22–.61	>.05	.10 ± .32	.53–.74	>.05	.42 ± .29	.16–1.00	>.05	.33 ± .23	.12–.79	>.05
Posterolateral (inches)	Control vs Tape	.03 ± .21	.38–.48	>.05	.04 ± .31	.57–.65	>.05	1.36 ± .29	.78–1.94	<.01*	1.46 ± .30	.88–2.05	<.01*
	Control vs Bandage	.16 ± .21	.38–.48	>.05	.12 ± .31	.49–.73	>.05	1.70 ± .29	1.12–2.28	<.01*	1.97 ± .30	1.39–2.56	<.01*
	Tape vs Bandage	.19 ± .21	.22–.60	>.05	.08 ± .31	.53–.70	>.05	.34 ± .30	.24–.93	>.05	.51 ± .30	.08–1.10	>.05
Composite score	Control vs Tape	.01 ± .15	.29–.31	>.05	.44 ± .33	.22–1.11	>.05	2.81 ± .20	2.42–3.20	<.01*	2.72 ± .18	2.36–3.08	<.01*
	Control vs Bandage	.15 ± .15	.15–.44	>.05	.42 ± 33	.24–1.09	>.05	2.47 ± .20	2.08–2.86	<.01*	2.40 ± .18	2.04–2.76	<.01*
	Tape vs Bandage	.16 ± .15	.14–.46	>.05	.02 ± .34	.65–.69	>.05	.34 ± .20	.06–.73	>.05	0.32 ± 0.18	0.04–0.68	>.05

MD: Mean difference, SD: Standard error, CI: Confidence interval, P: Probability, *: Significant.

Table 6
Repeated measure ANOVA of Vertical Jump Height between the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support	Immediately after support			2 weeks after support			2 months after support		
		M±SD	M±SD	95%CI	P	M±SD	95%CI	P	M±SD	95%CI	P
Jump Height (inches)	Tape	61.00 ± 1.90	61.61 ± 1.20	.22–1.43	<.01*	64.61 ± 1.77	2.79–4.42	<.01*	65.67 ± 1.29	3.88–5.45	<.01*
	Bandag	61.06 ± 1.90	61.64 ± 1.32	.25–1.40	<.01*	64.36 ± 1.17	2.58–4.03	<.01*	65.97 ± 1.08	4.15–5.67	<.01*
	Control	60.32 ± 1.37	60.74 ± 1.26	.20–1.02	<.01*	63.09 ± 2.05	2.02–3.51	<.01*	64.56 ± 1.16	3.61–4.86	<.01*

M: Mean, SD: Standard deviation, CI: Confidence interval, P: Probability, *: Significant.

Table 7
Independent measure MANOVA between the intervention and control groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

		Before support			Immediately after support			2 weeks after support			2 months after support		
		MD ± SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P	MD±SE	95%CI	P
Jump Height (inches)	Control vs Tape	.68 ± .43	.17–1.52	>.05	.87 ± .31	.26–1.48	<.05*	1.52 ± .42	.69–2.36	<.01*	1.11 ± .29	.54–1.68	<.01*
	Control vs Bandage	.74 ± .43	.11–1.58	>.05	.90 ± .31	.29–1.51	<.05*	1.28 ± .42	.45–2.10	<.04*	1.41 ± .29	.84–1.98	<.01*
	Tape vs Bandage	.06 ± .43	.79–.91	>.05	.03 ± .31	.59–.56	>.05	.24 ± .42	.59–1.08	>.05	.30 ± .29	.27–.88	>.05*

MD: Mean difference, SD: Standard error, CI: Confidence interval, P: Probability, *: Significant.

The results of the current study showed that all external supports non-significantly increased ankle proprioception immediately after one session, and this is maybe because ankle taping and bandaging could cause immediate limitation to the ankle plantarflexion movement which leads to a decrease in the functional performance; however, after some time the body could be used to the tape and bandage and start to increase the firing rate of cutaneous and mechanoreceptors which lead to an increase in the ankle stability and balance (Cordova et al., 2005). These results following the results of (Bicici et al., 2012; Delahunt et al., 2010; Halim-Kertanegara et al., 2017; Hettle, 2013) who have demonstrated that ankle joint taping cannot improve functional instability, functional performance, static and dynamic balance control, or reaching distance among individuals with CIA because of its

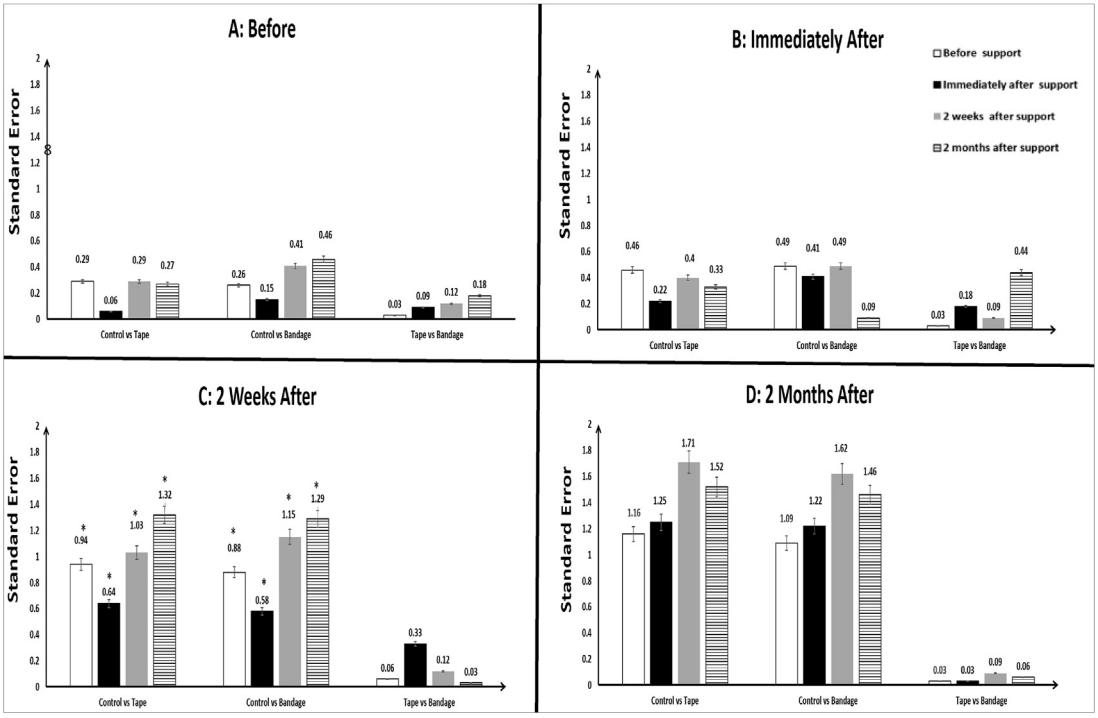

Fig. 3. Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support *: Significant.

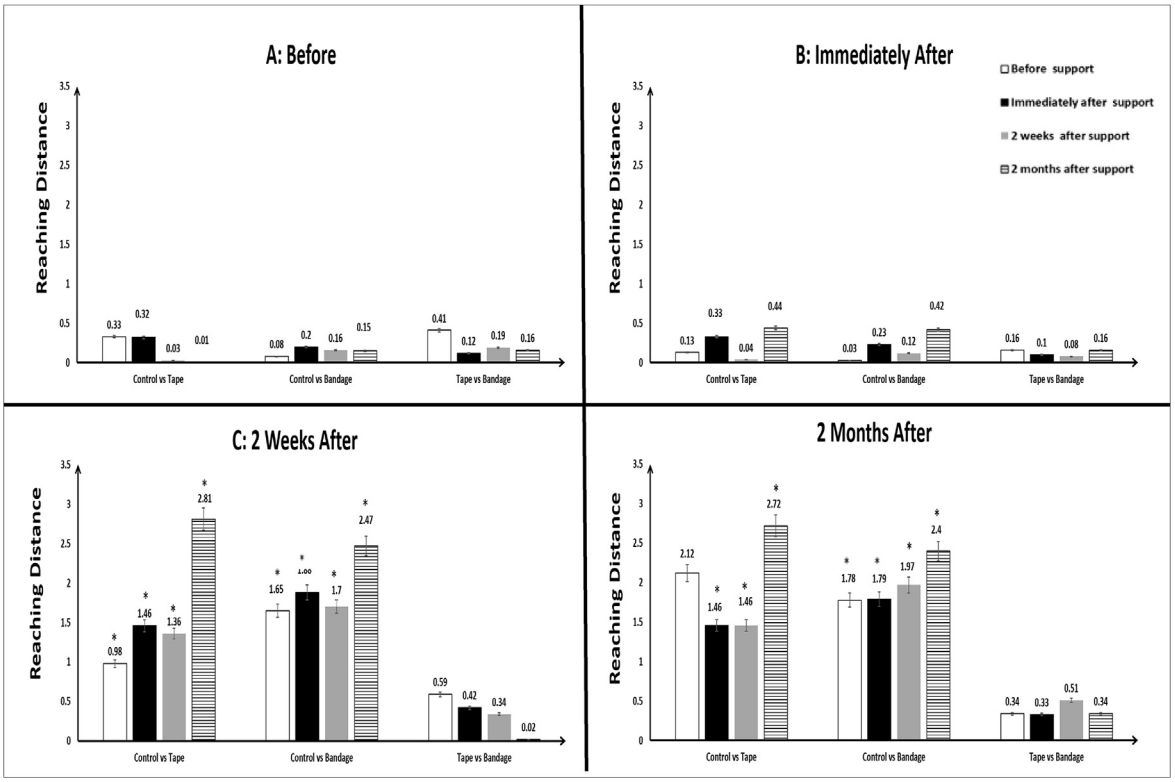

Fig. 4. Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

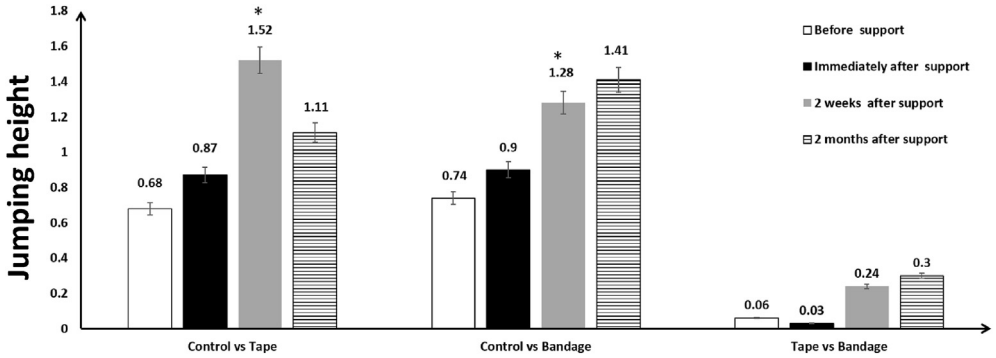

Fig. 5. Independent measure MANOVA between the intervention and control groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

movement-limiting effect.

Both taping and bandaging significantly increased ankle proprioception after 2-weeks and 2-months. The improved proprioception in this study might be related to the close contact between either the taping or bandaging and the skin, which increased the firing rate of cutaneous receptors, particularly, the mechanoreceptors; which helped in improving the precise foot position sense. Also, taping and bandaging may provide more cutaneous cues that increase the muscle afferents at the spinal cord level and increase the motor neuron pool excitability (Feuerbach et al., 1994). Besides taping and bandaging have been reported to increase the perceptions of stability, confidence, and reassurance (Sawkins et al., 2007; Sekizawa et al., 2001; Winter et al., 2003). Increasing both cutaneous and muscle mechanosensory cues cause a central improvement in spinal processing time (Eriksson, 2001; Kaya, 2016; Mohamed, 2019; Mohamed, Jan, El Sayed, El Wanis, & Yamany, 2012). Modifying proprioceptive inputs by increasing mechanoreceptors' feedback induces plastic adjustments in the central nervous system. This mainly occurs through improving the γ (gamma) pathway to allow more control of postural reflexes and motor control (Mohamed, Jan, El Sayed, El Wanis, & Yamany, 2012; Vallbo et al., 1990).

These results following the results of previous studies. Simoneau et al. (Simoneau et al., 1997) has reported that increased cutaneous sensory feedback, provided by strips of athletic tape which applied across the ankle joint of healthy individuals, helped in improving ankle joint position perception in non-weight-bearing activities, especially for the midrange plantar-flexed ankle position (Simoneau et al., 1997). Iris et al. (Iris et al., 2010) also have indicated that ankle taping improved proprioception in healthy participants (Iris et al., 2010). They argued this improvement to the same mechanism demonstrated in the study of Simoneau et al. (Simoneau et al., 1997). Isabel et al. (Alguacil-Diego et al., 2018), who have reported that both bandaging and taping can equally increase postural sway among individuals with ankle instability.

Taping and Bandaging also did not significantly increase balance immediately after one session, while they significantly increased balance after 2 weeks and 2-months. The balance improvement in this study is related to the effect of taping and bandaging on improving the proprioception which accounts for 70% of feedback sent to the central nervous system in order to control both static or dynamic balance (Mohamed, 2019). Also, providing an accurate joint position sense causes more control over joint position causing an increase in the reaching distance of the free swing leg (Lee & Lee, 2015).

The results of this study came following the results of the study of Jackson et al. (Jackson et al., 2016), who have demonstrated that Kinesio taping increased balance after 48 h. Lee et al. (Lee & Lee, 2015), who have reported that ankle taping improves dynamic balance among young male soccer players with CAI (Lee & Lee, 2015). Someeh et al. (Someeh et al., 2015) have indicated that fibular repositioning taping improves postural control among healthy athletes and athletes with CAI.

In this study, both taping and bandaging significantly increased vertical jump immediately after one session, after 2 weeks and 2-months. The improved vertical jump in the present study might occur because external supports could help individuals with CAI to compensate for their impaired neuromuscular control by afferent feedback mechanisms and increase mechanical stability (Wikstrom et al., 2006). Besides, external supports could increase the sensorimotor system activities including active ankle movements position sense and ankle joint (Feuerbach et al., 1994; Jerosch et al., 1995). Jumping capability significantly depends on the strength of the neuromuscular system, which helps in producing proper muscle coordination through jumping (39). Proprioception feedback is essential for the central nervous system to increase the quality of the performed movements. Thus, precise proprioception feedback for the position of body segments in relation to each other and the ground during jumping is essential for proper production of motor commands and facilitation of optimal performance (Struzik et al., 2017).

The results of this study came following the results of the study of Hadadi et al. (Hadadi & Abbasi, 2019) who have demonstrated that ankle orthoses with soft orthosis significantly improve both static and dynamic postural stability. Contrary, Abián-Vicén et al. (Abián-Vicén et al., 2008) have demonstrated that ankle taping does not negatively affect jumping or balance tests, contrast it increases the vertical force, which can cause a higher risk of injury accompanying the accumulation of repeated impacts in athletic activities where jumps are commonly performed. Some studies have found that Kinesio taping has a non-significant immediate effect on both athletic performances and jump ability because ankle taping slightly modifies the position of the COP through jumping leading to a decrease in athletes' performance (Nunes et al., 2013; Vinken, 2015).

The weaknesses of this study were that taping and bandaging may decrease their tight after some time because of walking and washing; we replaced the external support every two weeks to decrease this issue. Also, all included participants were young athletes because of increased the rate of sports participation in this age (Bicici et al., 2012). This study did not investigate differences between males and females and there were no follow-up measurements because the main aim was to investigate the long-term effects of tapping. Future studies should investigate differences in the long-term effects of taping on between genders. Besides, future studies should investigate the possibility of these significant effects

to last for up to 6 months or more.

5. Conclusion

The current study indicated that ankle taping and bandaging immediately improve vertical jump only; while they improve proprioception, balance, and vertical jump after 2 weeks and 2 months. Thus, both tapping and bandaging should be prolonged to produce an improvement in ankle joint proprioception, vertical jump, and balance among volleyball players with CAI.

Ethical statement

All the participants who participated in our study were asked to deeply read the study procedures and sign a detailed consent form before starting the procedures. This study was conducted in the physical therapy and rehabilitation laboratories in Istanbul Gelisim University – Turkey. This study was approved by the ethics committee of Istanbul Gelisim University. The registration number of this study protocol is NCT04377269.

Declaration of competing interest

None.

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