Influence of pelvic padding and Kinesiology Taping on pain perception, kinematics, and kinetics of falls in female volleyball athletes

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Abstract
Background: Volleyball digging techniques may cause pelvic injuries among female volleyball athletes. Pelvic padding and Kinesiology Taping (KT) may reduce impact force and pain and improve posture during a fall. This study examined the effects of pelvic padding and KT on pain perception, fall kinematics, and kinetics among female volleyball athletes.
Methods: Twenty-four female volleyball athletes were exposed to two pelvic padding scenarios (with and without padding) and two KT conditions (with and without KT applied on the rectus abdominis muscle) during a fall in the forward direction. The maximum impact force during landing and maximum acceleration of the pelvis were registered using a force platform and an accelerometer, respectively. The maximum lumbar (hyper)extension angle, forward reach distance, and total fall time were measured by video analysis. Pain level was quantified using a visual analog scale.
Results: The application of pelvic padding (with and without KT) reduced pain when compared to the no padding condition ($p<0.008$). Applying KT alone reduced forward reach distance when compared to the 'pelvic padding and KT' condition ($p<0.010$). In fact, when both pelvic padding and KT were applied, participants reached further when compared to the 'no pelvic padding and no KT' condition ($p<0.001$). No significant main and interaction effects were found in all other outcomes.
Conclusions: Volleyball shorts with pelvic pads are recommended for female volleyball athletes to reduce pain in the digging maneuver and may help to increase their forward reach distance. However, KT is not recommended as it reduces the forward reach distance and cannot reduce pain or improve fall kinematics and kinetics.

Keywords: Taping; pelvic pads; volleyball; fall motion; impact force; pain

1. Introduction

Volleyball is a popular team sport among younger people worldwide. Effective defensive drills (e.g., digging maneuver) are crucial for success in volleyball competitions, and hence, are emphasized in training [1,2]. However, repetitive practice of defensive techniques could lead to musculoskeletal injuries such as ankle sprains and knee, back, and shoulder overuse injuries [3,4]. In particular, the diving and digging maneuver may lead to high pelvic impact loading and possibly injuries among female volleyball athletes when they fall on the ground and land on their pelvis [2,5,6]. Volleyball shorts with pelvic protector pads placed over the bilateral anterior superior iliac spine (ASIS) regions are available in the market as a kind of protective gear to reduce pain and prevent fall-related pelvic injuries [7]. However, its effects on pain perception, fall kinematics, and kinetics have not been investigated scientifically. Therefore, the first aim of this study was to examine the effects of pelvic padding on pain perception, fall kinematics, and kinetics among female volleyball athletes.

Kinesiology Taping (KT) is a kind of elastic adhesive tape commonly used by athletes to reduce pain, improve circulation, and facilitate muscle contraction [8-10]. A previous study has reported that the application of KT on the rectus abdominis muscle could improve strength and endurance of the muscle in women who underwent a cesarean section [11]. Since the rectus abdominis muscle causes posterior pelvic tilt when it contracts concentrically [12], we postulated that the application of KT on the rectus abdominis muscle may facilitate its contraction; thereby, improving pelvic position (decrease anterior pelvic tilt and lumbar hyperextension) during the volleyball digging maneuver (i.e., a fall in the forward direction). As a result, the impact force acting on the bilateral ASIS regions of female volleyball athletes during landing may be reduced and pain may be reduced as well. However, no study has investigated KT's effects on fall motion and impact force thus far. The second aim of this study was to examine the effects of KT on pain perception, fall kinematics, and kinetics among female volleyball athletes. Since both pelvic padding and KT may be used together in practical situations, the third aim of this study was to examine the interaction effect of pelvic padding and KT on pain perception, fall kinematics, and kinetics among female volleyball athletes. It was hypothesized that both pelvic padding and KT (when applied separately or together) may reduce pain and improve fall kinematics and kinetics among the athletes.

2. Methods

2.1. Participants

This was a one-group experimental study with a repeated-measures design. Between November and December 2017, participants were recruited from four local volleyball clubs by convenience sampling. The inclusion criteria were: between 18 and 30 years old, woman, had a minimum of three years of volleyball experience and played at the recreational level, and had mastered the volleyball diving and digging techniques. Those recruits with recent musculoskeletal injuries or other orthopedic problems (e.g., low back pain) that could affect the test performance, with significant neurological or balance disorders, receiving martial arts or balance training regularly, or having an adhesive tape allergy were excluded. The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster. Informed written consent was obtained from each participant and all procedures were performed according to the Declaration of Helsinki.

Basic demographic information was obtained by interviewing the participants. Subsequently, body weight and height were measured, and body mass index was calculated. Leg length (from ASIS to ipsilateral medial malleolus) was measured using a cloth measuring tape. Habitual physical activity level was quantified using the International Physical Activity Questionnaire short form. Volleyball training experience, time, frequency, and intensity were also determined.

2.2. Outcome measurements

This study was conducted in the Physical Activity Laboratory of The University of Hong Kong by a physiotherapist and 4 student researchers. All participants underwent two pelvic padding conditions (i.e., with and without pelvic padding) and two taping conditions (i.e., with and without KT applied on the rectus abdominis muscle) during a fall in the forward direction. Six outcome measurements were included – (1) pain perception on impact, (2) pelvic impact force, (3) maximum vertical acceleration of the pelvis, (4) maximum lumbar extension angle, (5) forward reach distance, and (6) total time to complete the fall. The order of testing conditions was randomized, and all measurements were performed within the same day.

Before the fall assessment, participants were required to wear fitted-size volleyball shorts. Padding was added to the volleyball shorts (Zoombang Inc., Texas, US) to cushion the bony prominences of the pelvis (bilateral ASIS) during landing on the anterior pelvis for the two pelvic padding conditions (Fig. 1). Moreover, KT (Kinesio Tex Classic, Kinesio Holding Corporation, US) was applied on the rectus abdominis muscle following the procedures described by Ptak et al. [13] for the two KT conditions. In brief, two pieces of tape were applied longitudinally on the rectus abdominis from the level of the xiphoid process to the level of the pubic symphysis. The tape was placed using the muscle technique on a lengthened abdominal muscle so that the tape wrinkled a bit when the participant was standing [13].

During the fall assessment, participants were required to perform a forward fall, simulating the volleyball diving and digging maneuver. They were instructed to stretch out and reach forward as far and as fast as possible when they fell, as if they were diving for a volleyball spike in the front [6,14]. A force platform (FDM-SX, Zebris Medical GmbH, Isny, Germany), which was fixed on the floor, was used to record the maximum impact force when the participants fell on the anterior part of the pelvis (either on the left or right ASIS). The maximum impact force of each participant was then normalized against his/her own body weight, and thus, the outcome was expressed as a percentage of body weight. A uniaxial accelerometer (ACH-01, Measurement Specialties Inc., Hampton, VA, USA) was attached to the sacrum to register the maximum vertical acceleration of the pelvis during the fall. Fall motion of each participant was video-recorded and analyzed frame by frame using the Coach My Video software (www.coachmyvideo.mobi). The maximum lumbar extension angle (attained when the participant's dominant hand started to contact the ground) (Fig. 2) and maximum forward reach distance (measured from the point where the heel of the dominant leg struck the ground to where the dominant hand touched the ground) were determined visually by one of the student researchers. The total time required to complete the fall (i.e., when the participant stood on one leg before the fall to when the dominant hand touched the ground) was also documented. A longer forward reach distance and a shorter fall time indicated better sports performance. The fall assessment procedures can be retrieved from https://youtu.be/o47pZyJRDog.

After each fall maneuver, participants were asked to quantify their perceived pain level in the pelvic region during landing by using the visual analog scale (VAS). A score of 0 indicates no pain while a score of 10 indicates extreme pain [15]. A familiarization trial was allowed for all participants to familiarize themselves with the forward falling and sliding motions before the testing trial (actual measurements) for each condition.

2.3. Statistical analysis

Power analysis was performed using the GPower 3.1 software (Franz Faul, University of Kiel, Germany). Assuming a medium effect size of 0.25, a two-tailed alpha level of 0.05, and a power of 0.8, a minimum of 24 participants were needed for this study.

Data were analyzed using IBM SPSS 24.0 software (IBM, Armonk, NY). The overall significance level was set at 0.05 (two-tailed). Two-way repeated measures analysis of variance (ANOVA, within-subject factors: pelvic padding and KT) was used to compare pain level, fall time, forward reach distance, maximum pelvic acceleration, and impact force, and the maximum lumbar extension angle across different pelvic padding and KT conditions. A post hoc paired t-test with the Bonferroni correction was performed if any overall significant results were obtained for the outcome variables. The effect size (partial eta-squared (η_p^2)) was also reported. By convention, values of 0.14, 0.06, and 0.01 denote large, medium, and small effect sizes, respectively [16].

3. Results

Twenty-four female volleyball athletes were recruited. All were eligible to participate in the study and completed the assessments. No injury or adverse events were reported during the fall assessments. The characteristics of the participants are detailed in Table 1.

Regarding the pain level, there was an overall significant main effect of the pelvic padding condition ($F_{1,23}$ = 16.990, p <0.001, η_p^2 = 0.425), but the main effect of the KT condition ($F_{1,23}$ = 2.943, p = 0.100, η_p^2 = 0.113) and the pelvic padding-KT condition interaction effect ($F_{1,23}$ = 2.406, p = 0.135, η_p^2 = 0.095) were not significant. In the post hoc analysis of the main effect of the pelvic padding condition, the application of padding to the pelvis reduced pain significantly by 1.46 points to 1.96 points when compared to the no pelvic padding conditions (pelvic padding only vs. KT only: p <0.001; and pelvic padding only vs. no pelvic padding and no KT: p <0.001). When both pelvic padding and KT were applied, the pain level was reduced by 1.54 points when compared to the KT only condition (p = 0.002), and 2.04 points when compared to the no pelvic padding and no KT condition (p = 0.001) (Table 2).

For the maximum pelvic impact force, there were no significant main effects of the pelvic padding condition ($F_{1,23}$ = 0.236, p = 0.632, η_p^2 = 0.010) and KT condition ($F_{1,23}$ = 0.128, p = 0.724, η_p^2 = 0.006). The pelvic padding-KT condition interaction effect was also not significant ($F_{1,23}$ = 0.449, p = 0.509, η_p^2 = 0.019). Same as the maximum pelvic acceleration outcome – no significant main effects (pelvic padding condition: $F_{1,23}$ = 0.225, p = 0.640, η_p^2 = 0.010; and KT condition: $F_{1,23}$ = 1.691, p = 0.206, η_p^2 = 0.068) and interaction effect ($F_{1,23}$ = 1.437, p = 0.243, η_p^2 = 0.059) were noted. Regarding the maximum lumbar extension angle, no significant main effects (pelvic padding condition: $F_{1,23}$ = 2.995, p = 0.097, η_p^2 = 0.115; and taping condition: $F_{1,23}$ = 1.516, p = 0.231, η_p^2 = 0.062) and interaction effect ($F_{1,23}$ = 1.420, p = 0.246, η_p^2 = 0.058) were found as well (Table 2).

A significant main effect of the KT condition was detected in the forward reach distance ($F_{1,23}$ = 27.098, p < 0.001, η_p^2 = 0.541). However, the main effect of the pelvic padding condition ($F_{1,23}$ = 1.934, p = 0.178, η_p^2 = 0.078) and the pelvic padding-KT condition interaction effect ($F_{1,23}$ = 1.119, p = 0.301, η_p^2 = 0.046) were not significant. Post hoc analysis of the main effect of the KT condition showed that the application of KT alone reduced forward reach distance by 0.11 m when compared to the pelvic padding and KT condition (p < 0.010). When both pelvic padding and KT were applied, forward reach distance increased by 0.12 m when compared to the no pelvic padding and no KT condition (p < 0.001) (Table 2).

As for the fall time, results showed that the pelvic padding condition main effect ($F_{1,23}$ = 0.545, p = 0.468, η_p^2 = 0.023), KT condition main effect ($F_{1,23}$ = 0.590, p = 0.450, η_p^2 = 0.025), and the pelvic padding-KT condition interaction effect ($F_{1,23}$ = 0.767, p = 0.390, η_p^2 = 0.032) all were not statistically significant (Table 2).

4. Discussion

4.1. Pain level

The most encouraging finding of this study was that pelvic paddings, when applied on the bilateral ASIS regions, could reduce pain mildly (pain reduced by 1.46 – 2.04 points) [17] when female volleyball athletes fell on the anterior part of their pelvis after a fall in the forward direction. This finding was not entirely surprising as the soft padding, which is similar to an external hip protector, may attenuate some of the impact or frictional forces when the participants fell on the bony prominences of the pelvis [18]. The addition of KT did not reduce pain further, and indeed, the application of KT had no effect on pain perception. This hints that KT may not be able to facilitate effective contraction of the abdominal muscles [13] nor control the anterior pelvic tilting angle and lumbar (hyper)extension during a fall in the forward direction. Thus, participants still fell on their bony ASIS, which can be quite painful.

4.2. Maximum pelvic impact force

In some contrast to our hypothesis, we found that the maximum impact forces when falling on the anterior pelvis were similar across all pelvic padding and KT conditions. There are two plausible explanations. First, we measured impact forces using a force platform mounted on the floor. Thus, it may not be able to detect the shock absorption effect of the pelvic padding. Further studies should fix pressure sensors on the ASIS to register the impact force that was transmitted to the skin surface through the pelvic padding during landing [18]. Second, previous research has suggested that impact force attenuation is highly sensitive to variations in impact velocity, pelvic size, and soft tissue stiffness [19]. Joint movements and muscle actions also play a major role in peak force reduction during landing [20]. We did not control for these extraneous factors (impact velocity, pelvic size, pelvic soft tissue stiffness, joint movements, and muscle actions) during the assessments, and hence, they may have confounded the results.

4.3. Maximum pelvic acceleration

Our results also revealed that both pelvic padding and KT did not affect the maximum pelvic acceleration during an intentional fall in the forward direction. Since participants reported less pain on landing when pelvic padding was applied, they were expected to accelerate or shorten the fall time. Further studies may explore why this was not the case. As for the application of KT, since it could not reduce pain perception and was unable to alter the force-velocity parameters of the abdominal muscles [13], it was logical that KT did not affect the maximum pelvic acceleration of the volleyball athletes during the fall.

4.4. Maximum lumbar extension angle

The maximum lumbar extension angles that reflect the lumbar-pelvic position of the athletes during a fall were similar across all KT and pelvic padding conditions. This finding was a bit surprising as a previous study reported that applying KT on the rectus abdominis for 4 weeks could improve muscle contraction in women who underwent a cesarean section [11]. Theoretically, activating the rectus abdominis muscle could prevent excessive anterior pelvic tilt and lumbar (hyper)extension during a fall [21]. In the present study, KT was applied for less than 30 minutes, and thus, it may not be able to activate the abdominal muscles effectively [22]. The use of pelvic padding may not be useful as well because it was only applied on the bilateral ASIS. Further studies may employ a longer KT application time [22] and should measure the adverse effects associated with lumbar hyper extension (e.g., low back pain) [23] among volleyball athletes. The relationship between maximum lumbar extension angle and volleyball performance could also be measured in future studies.

4.5. Forward reach distance

Our results showed that the application of KT alone reduced forward reach distance but when pelvic padding was added, the forward reach distance increased. It may be because applying KT on the rectus abdominis muscle (originated from the xiphoid process and 5th–7th costal cartilages all the way down to the pubic symphysis and pubic crest) [12] may hinder the participants from stretching out and reaching forward. Since wearing pelvic padding could reduce pain when falling on the pelvis, the participants might have better confidence to reach further during a fall. Future studies could measure the fear of falling or fall-related efficacy [24] when the volleyball athletes fell with and without pelvic paddings to confirm this postulation.

4.6. Time to complete a fall

Volleyball athletes train hard to shorten the fall time while on defense. This is because the lesser the time they use to complete a fall, the higher the chance they have of performing a successful digging maneuver [14]. However, we found that applying pelvic padding and/or KT did not affect the fall time. It could be because pelvic padding was designed for only protecting the athletes from fall-related injuries [7]. Even when the participants perceived less pain when they fell on the padded ASIS area, fall time (a performance measure) did not change significantly. Furthermore, applying KT on the abdominal muscles had no direct effect on the fall kinematics as described above, and hence, the fall time.

4.7. Limitations and practical applications

This study has some limitations in addition to those mentioned above. First, the abdominal muscle activity was not measured because we were worried that the impact force when landing on the pelvis may damage the electromyographic electrodes and hurt the participants. Further studies may use flexible electrodes [25] to detect abdominal muscle activity during a fall with or without KT/pelvic padding. Second, accuracy of the kinematic assessments can also be improved by using a motion analysis system to detect the lumbar, pelvic, and hip joint movements during a fall. Third, sports performance was not measured directly in this study. Future studies may, for example, measure the number of times the participants dived and dug successfully with or without KT/pelvic padding. The impact force in the horizontal direction (along the floor surface) or sliding direction could also be measured as it could be a useful kinetic data to reveal the performance of the athletes. Finally, since the study was performed among recreational volleyball athletes, our results cannot be generalized to volleyball athletes at other playing levels.

Nevertheless, our results suggested that wearing pelvic pads could reduce pain associated with falls and increase the forward reach distance. Hence, coaches could recommend shorts with pelvic pads to female volleyball athletes to increase comfort and probably improve sports performance. However, applying KT on the rectus abdominis muscle conferred no immediate benefits in improving the pain perception, kinematics, and kinetics during a fall among female volleyball athletes. It may even reduce the forward reach distance, and hence, may be detrimental to sports performance.

5. Conclusions

Pelvic padding could reduce pain and increase the forward reach distance during a fall among female volleyball athletes. Applying KT on the rectus abdominis muscle may, on the contrary, reduce the forward reach distance, and cannot reduce pain perception nor improve fall kinematics and kinetics in these athletes. Applying both pelvic padding and KT had no immediate effect on pain perception, fall kinematics and kinetics in this athletic population.

Conflict of interest

The authors declare that they have no conflicts of interest.

Acknowledgements

The authors would like to thank Mr. Chris Yeung, Mr. Cheung Chun Lok, and Miss Cheung Sze Wan for their assistance in data collection.

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Tables

Table 1

Characteristics of the female participants (n = 24)

Variable	Value
Age (year)	21.3 ± 1.7
Weight (kg)	52.5 ± 5.3
Height (cm)	161.4 ± 5.4
Body mass index (kgm^{-2})	20.1 ± 1.7
Volleyball experience (year)	6.8 ± 2.7
Volleyball training time (hours per week)	5.1 ± 2.4
IPAQ total physical activity per week (MET minutes per week)	734.8 ± 472.5

Values are means ± standard deviations.

MET = metabolic equivalent, IPAQ = International Physical Activity Questionnaire

Table 2
Outcome measures in the four testing conditions (n = 24)

Testing condition	Pain level	Maximum pelvic impact force (% of body weight)	Maximum pelvic acceleration (ms^{-2})	Maximum lumbar extension angle (°)	Forward reach distance (m)	Fall time (s)
1. Pelvic padding and KT	1.00 ± 1.22[a,c]	90.89 ± 54.22	0.83 ± 0.24	151.53 ± 8.41	1.65 ± 0.13[a,c]	1.45 ± 0.22
2. KT only	2.54 ± 2.43[a,b,d]	101.35 ± 64.44	0.81 ± 0.22	155.17 ± 7.38	1.54 ± 0.16[d]	1.40 ± 0.17
3. Pelvic padding only	1.08 ± 1.28[a,c]	103.42 ± 68.87	0.86 ± 0.21	154.40 ± 8.08	1.61 ± 0.16[a]	1.40 ± 0.19
4. No pelvic padding and no KT	3.04 ± 3.11[b,d]	101.72 ± 71.26	0.82 ± 0.27	154.77 ± 8.95	1.53 ± 0.15[b,d]	1.41 ± 0.21

Values are means ± standard deviations.
[a] P <0.008 (Bonferroni adjusted) compared with no pelvic padding and no KT condition (testing condition 4).
[b] P <0.008 (Bonferroni adjusted) compared with pelvic padding only condition (testing condition 3).
[c] P <0.008 (Bonferroni adjusted) compared with KT only condition (testing condition 2).
[d] P <0.008 (Bonferroni adjusted) compared with pelvic padding and KT condition (testing condition 1).

Figures

Figure 1.
The volleyball shorts and pelvic padding.

Figure 2.
The experimental set-up and measurement of the maximum lumbar extension angle (when the dominant hand came into contact with the ground).