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ORIGINAL

Immediate and mid-term effects of elastic taping on gymnast's postural control performance during a handstand

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

abstract

Background The study explored whether three different applications of an elastic tape on the forearms of healthy, active gymnasts influence their postural control performance during a handstand immediately and 48 hours after application.

Material/Methods 24 gymnasts were randomly assigned to three groups: group 1 – elastic tape application at a gymnast's wrist joints, group 2 – elastic tape application at a gymnast's forearm muscles, and group 3 – a combination of groups 1 and 2. The gymnast's center of pressure was measured with a mobile balance platform, indicating postural control performance during a handstand.

Results The gymnast's postural control performance during a handstand is affected depending on the elastic tape application and the time span the application is in situ. Elastic tape application on a gymnast's wrist joints reveals a performance increase immediately and 48 hours after application. Elastic tape application on a gymnast's forearm muscles increases performance when applied for 48 hours. Combined elastic tape application does not additionally affect gymnast's postural control performance.

Conclusions Elastic tape applications can increase postural control performance during a handstand. Furthermore, it is supposed that mechano-sensory stimulation, improved attention and awareness due to elastic tape application and the belief in its effectiveness may be moderating mechanisms of this effect.

Key words kinesiotaping, Wii balance board, athletic performance, gymnasts, handstand

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INTRODUCTION

Using elastic tape straps in applied sport has become popular in the last few years. The primary aim in using these tape straps is to support athletic performance or recovery, when athletes are suffering from an injury, or in case of restricted muscle or joint functioning due to overuse and/or harm. However, elastic tape straps may also be used in terms of prevention, or even performance enhancement in an active and healthy athlete [1]. Therefore, the aim of this study was to explore whether the application of elastic tapes on the forearm may influence sport specific postural control performance of gymnasts performing a handstand. In order to approach this aim, three different applications of elastic tapes at the forearm were examined to influence postural control performance during a handstand in three different measurements, before, immediately after and 48 hours after elastic tape application.

There are several conceptualizations for the cotton elastic tape straps. These conceptualizations are for instance kinesio tape [2, 3], kinaesthetic-tape [4], and elastic tape [5]. There are also specific brand names, such as Kinesio® Tape, K-Tape®, Kintex™, etc. In this manuscript the term elastic tape is used, referring to cotton tape straps which can be stretched longitudinally up to 120-140% of their original length, and shorten after they are attached to the skin [6].

Elastic taping is hypothesized in sport prevention and sport rehabilitation to improve body functioning aiming to influence muscle and joint functioning, blood and lymph flow and in dealing with pain [7]. As far as muscle functioning is concerned, it is argued that, depending on the aim and technique of the elastic tape application, concentric or eccentric stretch is induced to the muscle fascia which may influence either muscle contraction or muscle release [2, 8, 9, 10]. Joint functioning is argued to be influenced due to the tension of the skin, which in turn stimulates mechanoreceptors of the joint, leading to an improved proprioception and resulting in an improved joint alignment and joint control [6, 11, 12]. Therefore, one could speculate that the application of elastic tape straps on a gymnast's forearm muscles and wrist joints may have a positive influence on their postural control performance during a handstand.

However, overall implications of the effectiveness of elastic taping on athletic performance in general are quite inconclusive. Whereas some review articles are strongly questioning the clinical effectiveness of elastic taping [4, 13], others suppose small to medium effects of the elastic tape concerning muscle strength, a joint range of motion and functional performance [3, 14, 15].

The following studies focus on the effectiveness of elastic taping on functional and athletic performance of the upper limb in healthy subjects. Chang et al. studied the maximum grip strength and reproducibility of given grip intensities without elastic tape application, with elastic tape application on the wrist flexors and a placebo tape application. Results indicate that the reproducibility of given grip intensities is more precise when an elastic tape is applied on the wrist flexors compared to no tape and the placebo tape [16]. Lin et al. studied muscle activity via electromyography and pro-

prioception via reproducibility of the given arm end positions in healthy shoulders with and without an elastic tape application. Thereby muscle activity of the m. trapezius, m. deltoideus and m. serratus was affected by the elastic tape application and proprioception increased when an elastic tape was applied on the shoulder joint [17].

Whereas the two above-mentioned studies mainly focus on short-term effects of an elastic tape immediately after the tape application, practitioners argue that optimum effectiveness happens when the elastic tape is applied for one to three days [1, 7]. Several studies investigated the effectiveness of an elastic tape on parameters of muscle and joint functioning depending on measurements immediately after and one to four days after tape application. Slupik et al., for instance, found that relative peak torque changes of the m. vastus medialis via transdermal electromyography were affected depending on several measurements before, ten minutes, 24 hours, 72 hours and 96 hours after elastic tape application [18]. Fayson et al. measured ankle stiffness via static restraint and dynamic postural control via time to stabilization after one-legged hops before, immediately after and 24 hours after elastic tape application in 30 healthy women. Whereas ankle stiffness was positively affected immediately and 24 hours after elastic tape application, the time to stabilization was not [19]. Nakajima and Baldridge showed that female subjects increased dynamic balance measured via Star Excursion Balance Test (SEBT) before, immediately after and 24 hours after an elastic tape was applied with tension on the ankle stabilizers (m. tibialis anterior, m. triceps surae, m. peroneus) compared to the control group in which the same ankle stabilizers were taped but without any additional tension on the tape straps applied [20]. Nunes et al. also measured dynamic balance via SEBT when either an elastic tape or a non-elastic tape was applied on the m. triceps surae. Here, a subject's dynamic postural control was not affected by any tape application [21]. Vinken et al. state that depending on the elastic tape application dancers are able to increase their postural control performance during specific one legged dancing positions in such a way that an elastic tape application on the ankle joint increases postural control performance, whereas postural control performance is not affected when an elastic tape is applied on the dancer's lower leg muscles [22].

The sport specific postural control task chosen for this study is the handstand in (artistic) gymnastics. This was done because the handstand is part of (artistic) gymnastics training and competition in nearly each expertise and skill level, on a variety of apparatuses and one of gymnastics basic skills [23, 24]. The application of an elastic tape on the wrist joints and forearm muscles resulted from research findings indicating that superior handstand performance is primarily regulated by the wrist joint torques [25] and variance of joint angles at the wrist and shoulder joint [26]. Additionally, it is of special interest to explore possible performance related effects of elastic taping in gymnastics because the use of tapes, bandages and/or orthoses in gymnastic competitions is restricted unless they are skin-colored [27].

Resulting from that it is hypothesized that the results of the effectiveness of elastic taping on postural control performance in upright posture are transferrable to the postural control performance in an overhead postu-

re, namely the handstand. Additionally, it is hypothesized that this effect is modulated by elastic tape application, which is either applied to affect the wrist joint itself, the joint stabilizing muscles, or as a combination of both. Furthermore the question should be explored whether this influence is restricted to effect postural control performance immediately after elastic tape application and/or 48 hours after elastic tape application with the elastic tape in situ.

MATERIAL AND METHODS

PARTICIPANTS

In expectation of a medium effect (Cohen's $f > 0.25$) [28] $N = 24$ female gymnasts (age = 16 ±5 years) were randomly assigned to three groups with each group having a different tape application procedure: group 1 – elastic tape application at gymnast's wrist joints (WJTA), group 2 – elastic tape application at gymnast's forearm muscles (AMTA) and group 3 – combined elastic tape application at gymnast's wrist joints and forearm muscles (WJTA + AMTA). All participating gymnasts reported to practice artistic gymnastics at least five hours per week. They had an average training experience of ten years, participating in regional and national competitions. This level of expertise was chosen to assure that participants with an intermediate expertise level might have an appropriate scope to be affected by elastic tape applications [29]. Neither one of the gymnasts reported to have any upper extremity injury within the last five years, nor experience with the elastic tape applications used in this study. Gymnasts in all experimental groups were asked to perform handstands on a mobile balance platform during three measurements: a) before elastic tape application (Baseline), b) immediately after elastic tape application (IMM) and c) 48 hours after elastic tape application with the elastic tape in situ (48h). Gymnasts were informed about the general procedure of the study and gave their written consent prior to the study, which was carried out in accordance with the guidelines of the local ethical committee and in concordance to the declaration of Helsinki.

MEASURES AND INSTRUMENTS

Experimental Tasks. Gymnasts were instructed to perform handstands on a mobile balance platform (Wii Balance Board™, Nintendo, Japan) for four consecutive seconds. Starting from an upright standing position approximately 0.70 m before the mobile balance platform each gymnast starts her handstand performance in such a way that her hands could be placed on the mobile balance platform after a preparatory step and the upswing into the handstand position (see Fig. 1). After reaching the handstand position on the mobile balance platform the gymnast was instructed to maintain the four consecutive seconds of handstand performance and then was allowed to complete the handstand with a downswing back into an upright standing position. All gymnasts were familiar with the handstand performance implemented in this study and reported that they were not influenced by the mobile balance platform's size, surface or sensory discrepancy. Overall the experimental task of handstand performance is quite common in artistic gymnastics warm-up and training as well as a basic skill for advanced routines that gymnasts perform in competition [23]. Prior to each handstand, the gymnast was instructed to

maintain the handstand position as stable as possible. Additionally, average handstand performance was controlled first, visually by a trained coach who assured that each handstand performance was similar to each gymnast's overall handstand performance in training and second, via each gymnast's individual evaluation [30, 31]. The gymnasts were instructed that the elastic tape application supports handstand performance.

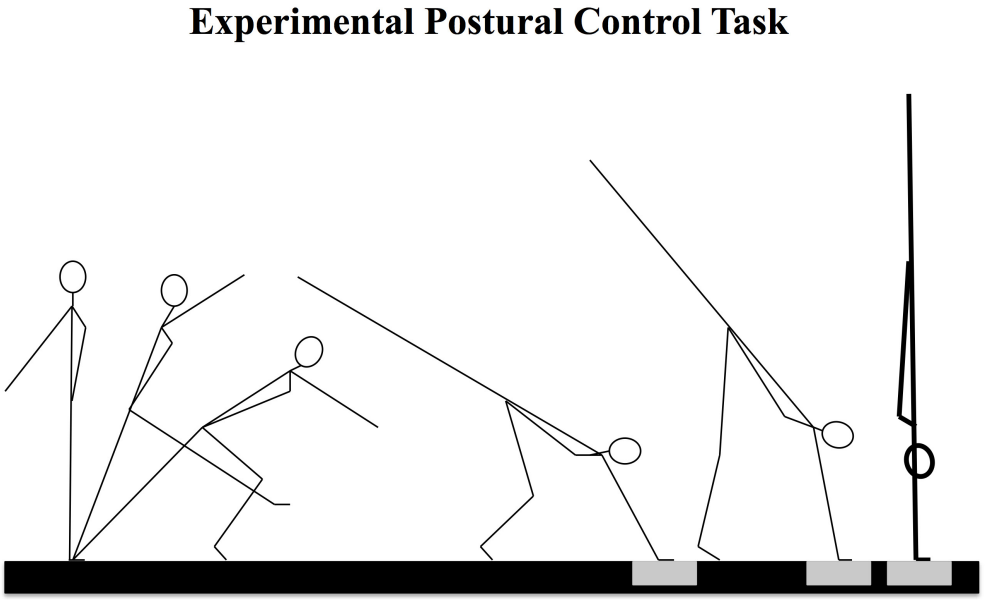

Fig. 1. Stick-figure sequence of the experimental postural control tasks implemented in this study, namely the handstand. Starting from an upright standing position the gymnast starts handstand performance by leaning forward, performing a preparatory step and placing the hands on the mobile balance platform (grey) to achieve the handstand position and stabilize this position (thick outline) for four consecutive seconds

Task Analysis. Gymnast's center of pressure sway (CoP-sway) in forward-backward and side-to-side-direction during a handstand performance was analyzed using a mobile balance platform (Wii Balance Board™, Nintendo, Japan) with a sampling rate up to 100 Hz. The mobile balance platform's CoP-signal was captured via Bluetooth and the software OSCulator (version 2.13.1, Wildora, 2014). Variable errors of CoP-sway were calculated reflecting the intra-individual regulation of gymnast's postural control performance with a larger variable error indicating a larger sway. Following the argumentation of previous studies [32, 33], variable errors of CoP-sway in forward-backward and side-to-side direction were calculated in order to represent gymnast's regulation of postural control performance during a handstand. Each gymnast was asked to perform four valid trials of handstand performance during each measurement. In order to get an estimation of gymnast's overall postural control performances during a handstand, means and standard errors of the variable error of CoP-sway were calculated, whereas forward-backward and side-to-side direction were merged.

Tape Application Procedures. The elastic tape applied in this study was a black, 5 cm wide, elastic tape (K-Tape®, biviax GmbH, Germany). The decision to use black tape throughout the whole study meant to avoid color preferences. Nevertheless, one may argue in line with the philosophy of elastic taping that a black elastic tape should enhance and empower muscle and joint functioning [1, 7].

Gymnasts in the first experimental group (WJTA) received an elastic tape application on both wrist joints. Therefore, one I-strap was applied on the palmar side of the wrist joint and another I-strap was applied on the dorsal side of the wrist joint. Both I-straps were applied with approximately 60-80% of stretch on the medio-lateral axis of the wrists joints [1] (see Fig. 2). Gymnasts in the second experimental group (AMTA) received an elastic tape application on the forearm muscles of both arms (wrist flexors and extensors, namely m. flexor carpi ulnaris et radialis and m. extensor carpi ulnaris, radialis longus et brevis). Therefore, four I-straps were applied in line with the wrist flexors and extensors with approximately 60-80% of stretch. Three of the four I-straps were longitudinally cut in half to avoid tape overlay [16] (see Fig. 2). Gymnasts in the third experimental group (WJTA + AMTA) received an elastic tape application combining the applications on the wrist joints and the forearm muscles of both arms. Therefore, one I-strap was applied on the palmar side of the wrist joint and another I-strap was applied on the dorsal side of the wrist joint. Additionally, four I-straps were applied in line with the wrist flexors and extensors. All straps were applied with approximately 60-80% (see Fig. 2). The elastic tape was applied with 60-80% of stretch because this amount of stretch is thought to stabilize the joint and to facilitate and activate the taped muscle [1, 7]. A professional taping expert was asked to apply all elastic tapes.

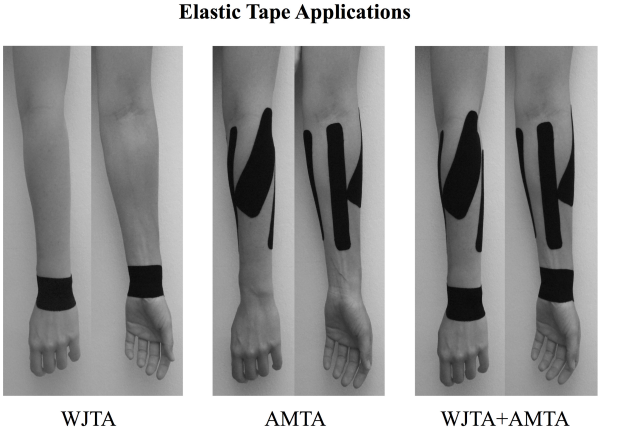

Fig. 2. Elastic tape applications used in this study. WJTA shows the elastic wrist joint tape application covering gymnast's wrist joint by two I-shaped tape straps. AMTA shows the elastic forearm muscle tape application covering gymnast's wrist flexor and extensor muscles by using four I-shaped tape straps. WJTA+AMTA shows the combined elastic tape application covering both, gymnast's wrist joint and arm muscles by using six I-shaped tape straps

PROCEDURES

The study consisted of six phases conducted on three consecutive days with the baseline measurement (BL) and the measurement immediately after an elastic tape application (IMM) conducted on the first day and the measurement 48 hours after elastic tape application (48h) conducted on the third day. During the first phase, the gymnast was instructed on the general purpose of the study and completed an informed consent form. The gymnast's height and weight was measured and the gymnast was given an individual, self-directed ten-minute warm-up phase consisting of mobilization drills, individualized stretching skills and preparatory handstand drills. Additionally, a pre-test was conducted to indicate each gymnast's individual handstand performance. Therefore, the gymnast was asked to perform two handstands with maximum handstand duration (cf. the section Gymnastics Coordination Test) [34] which was part of the randomization procedure to indicate similar general handstand performances within the three experimental groups. Afterwards, a practice period of at least four practice trials of handstand performances on

the mobile balance platform was conducted to familiarize the gymnast with the experimental task and the experimental setting.

The second phase consisted of the baseline condition (BL) without any elastic tape application in which the gymnast performed four valid handstand performances with a handstand duration of four consecutive seconds. When the gymnast failed to maintain the necessary four seconds, or handstand performance deviated from her standard performance, which was indicated by the gymnast herself and the coach, the trial was repeated. After the four trials of the baseline condition the gymnast received, depending on which experimental group she was assigned to, either an elastic tape application on her wrist joints, her forearm muscles or a combination of both. During each tape application condition, both arms were taped and after a ten-minute time slot to ensure full adhesive strength of the elastic tape [35] the following phase was conducted. In the third phase the gymnast performed the handstand performances immediately after elastic tape application (IMM). Here, similarly to the baseline measurement, the gymnast was asked to perform four valid handstand performances with the elastic tape application in situ. In the fourth phase the gymnast was instructed about handling the elastic tape application for the following two days until the next measurement and was released. In the fifth phase, 48 hours after the elastic tape application the gymnast was asked to perform another block of four valid handstand performances (48h). Here, similarly to the baseline measurement and the measurement immediately after elastic tape application, the gymnast was asked to perform four valid handstand performances with the elastic tape application in situ. In the sixth and last phase the elastic tape application was removed, the gymnast was debriefed and received a thank-you gift. There was no time pressure during the study and the gymnast was allowed to rest as needed.

DATA ANALYSIS

To indicate gymnast's differences in CoP-sway during the three measurements, percentage differences of measurements immediately and 48 hours after an elastic tape application to the baseline condition without elastic tape application were calculated. A significance level of $\propto = .05$ was defined for all results reported in this study. In the first step separate one-sample t-Tests against zero, with zero indicating the baseline measurement, were calculated for all group means. In the second step a 3 (Experimental Group) x 2 (Time) ANOVA with the percentage difference of CoP-sway as a dependent variable was calculated. Cohen's f was calculated for all reported significant results.

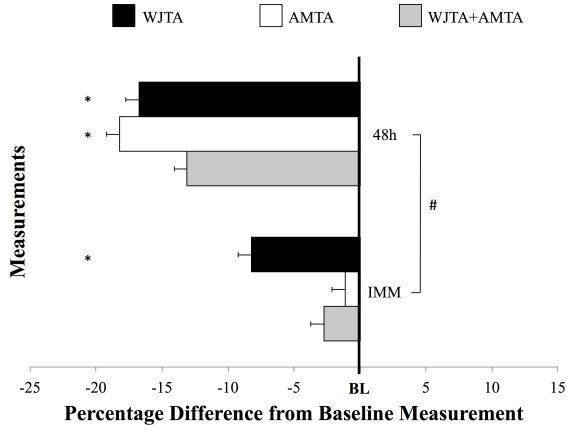

Fig. 3. Means and standard errors of the three experimental groups representing percentage differences of the measurements immediately after (IMM) and 48 hours after (48h) elastic tape application compared to the baseline measurement (BL) without elastic tape application (Note: negative values indicate lower CoP-sway compared to the baseline; * = significant difference at $p < .05$ according to one sample t-tests; # = significant difference according to Fisher LSD post-hoc test)

RESULTS

It was hypothesized that the elastic tape applications on gymnasts' forearms influence postural control performance during the handstand over time. Additionally, it was explored whether this influence differs among the three different elastic tape applications. Figure 3 shows means and standard errors of the three experimental groups representing percentage differences of the measurements immediately after (IMM) and 48 hours after (48h) elastic tape application to the baseline measurement (BL). In the measurement immediately after elastic tape application postural control performance during a handstand was significantly different from the baseline measurement when an elastic tape was applied on the wrist joints, $t_{WJTA\ IMM}(7) = 2.744$, $p = .029$, Cohen's $d = 0.959$. This became even more apparent 48 hours after elastic tape application on the wrist joints, $t_{WJTA\ 48h}(7) = 3.484$, $p = .010$, Cohen's $d = 1.232$, whereas when elastic tape was applied for 48 hours on the arm muscles postural control performance during a handstand had a tendency to be different compared to the baseline measurement without elastic tape $t_{AMTA\ 48h}(7) = 2.227$; $p = .061$, Cohen's $d = 0.787$. Additionally, there was a significant main effect for the factor Time, $F(1, 21) = 6.532$, $p = .018$, Cohen's $f = 0.558$. According to Fisher LSD post-hoc calculation, a significant difference for the arm muscle tape application occurs between the measurements immediately and 48 hours after elastic tape application.

DISCUSSION

The aim of this study was to explore whether three different applications of elastic tape on the forearms of active and healthy gymnasts influence their postural control performance during a handstand in three different measurements, before, immediately and 48 hours after elastic tape was applied. It was hypothesized that the elastic tape applications on gymnast's wrist joints, forearm muscle sand a combination of both affect their postural control performance during a handstand. Overall it was hypothesized that research findings of the elastic tape's effectiveness of postural control performance in the upright stance [20, 22] are transferable into an overhead posture, namely the handstand. In all elastic tape applications implemented in this study, gymnasts were instructed that each elastic tape application is supposed to facilitate postural control performance and that it should be explored what it is like immediately and 48 hours after the elastic tape application, compared to the baseline condition without an elastic tape.

Results indicate that gymnast's postural control performance during a handstand is affected depending on the elastic tape application and the time span the elastic tape application is in situ. Immediately after elastic tape application postural control performance during a handstand increased significantly compared to the baseline condition without an elastic tape, when the elastic tape was applied on the wrist joints. 48 hours after the elastic tape application the gymnast's postural control performance during a handstand significantly increases when elastic tape was applied on the wrist joints and trends to be significant when elastic tape is applied on the forearm muscles. Thereby, postural control performance significantly increases over time when elastic tape is applied on the arm muscles. A combination of both elastic tape applications reveals neither a significant increase in the postural control performance during a handstand immediately nor 48 hours after the elastic tape

was applied. However, the combined elastic tape application did not hamper postural control performance during a handstand. But when applied together, the performance increase effects of the wrist joint tape application and the arm muscle tape application do not function incrementally. Instead it seems possible that when applied together in a combined elastic tape application they mask each other's effects.

The increase in gymnast's postural control performance during a handstand seems to rely on the elastic tape application instead of a learning effect due to the experimental design. However, there are several limitations of the study, and three specific ones should be addressed. First, a mobile balance platform was chosen to measure gymnast's postural control performance during a handstand as a portable piece of equipment, thus enabling to test the gymnasts in their natural training environment. However, when using a force plate, more complex analyses such as inverse dynamic calculations estimating load parameters are possible. In light of the design of the study and implications of reliability and validity research of the Wii Balance Board [36, 37, 38] the device is applicable to measure CoP displacement in situations and conditions as indicated in this study design. Additionally, Leach et al. [38] indicate a significantly lower error in the forward-backward direction compared to the side-to-side direction. Therefore, it was decided to merge the variable error of CoP-sway in the forward-backward and side-to-side direction and to calculate the percentage error of overall CoP-sway to indicate gymnast's postural control performance during a handstand. Nevertheless, future studies may integrate a force plate and/or electromyographic measurements into their design to add more complex analyses and to indicate whether effects of postural control performance rely on diverse muscle activations. Additionally, a kinematic video analysis of the experimental task may complement parameters of the task execution. Second, although recent studies indicate effects of athletic performance when a control or placebo tape applications were implemented, it was chosen in this study to disclaim on such a tape application condition. This was most of all done due to practical considerations. A control tape application hypothesized to be effective had to be applied on the palm of the hand in comparison to the control tape application on the sole of dancer's foot [22]. Additionally, control or placebo tape applications as implemented in several other studies [16, 20, 21, 35] revealed no performance influencing effects on parameters of postural control. Furthermore, wrist flexors and extensors were taped simultaneously. However, various straps of elastic tape occurring in one tape application procedure may provoke different postural control performance during a handstand. Therefore, future studies should further investigate if and how separate elastic tape applications on gymnast's wrist flexors, for example in contrast to elastic tape application on gymnast's wrist extensors, affect their postural control performance during a handstand. Third, gymnasts in this study were asked to perform the handstand for four consecutive seconds before, immediately after and 48 hours after elastic tape applications with the elastic tape in situ to explore the effects of elastic taping on postural control performance during the handstand. One could argue that elastic taping may have different effects on handstand performance when perturbation and/or body transport are implemented in the experimental task. Additionally, it may be of interest to further study the effectiveness of elastic taping after more than 48 hours with the tape either in situ or in terms of a retention test after the elastic tape is removed.

There are at least two practical implications that can be summarized. First, gymnasts can, depending on the elastic tape application and the time span the tape is in situ, regulate their postural control performance during a handstand better when an elastic tape is applied either on their wrist joint or their forearm muscles. Thereby a combination of both elastic tape applications does not function incrementally. If this finding is transferable to apparatus specific to handstand performances, for example on the balance beam and/or the parallel bars, is yet speculative. Additionally, it should be kept in mind that the performance increasing effect in a postural control task may be different when the task demands vary, like for instance due to body transport. Second, and in line with the guidance argumentation, it is yet inconclusive if gymnasts may develop actual postural control performance during a handstand sufficiently and without being dependent on the elastic tape application, especially when it is applied in a skill learning environment. Although elastic taping can increase postural control performance during a handstand, the underlying mechanisms like for instance mechano-sensory stimulation due to the elastic tape application, improved attention and awareness on the taped body area, or the belief in its effectiveness can moderate parameters of athletic performance.

CONCLUSIONS

The effects of elastic tape applications for performance enhancing purposes are still inconclusive. Whereas former studies failed to report conclusive performance-enhancing effects concerning postural control performance in the upright posture, the results of the present study revealed a performance-enhancing effect concerning postural control performance in an overhead posture, namely the handstand. Additionally, this performance-enhancing effect depends on the implemented elastic tape application, whereas one elastic tape application reveals a performance increase immediately and 48 hours after elastic tape application (WJTA), another elastic tape application unfolds its performance-increasing effect only when applied for 48 hours (AMTA). However, when combining both elastic tape applications their performance-increasing effects do not add up. Instead one may argue that they mask each other's effects on gymnast's postural control performance. Furthermore, it should be kept in mind whether this performance-enhancing effect of elastic taping on gymnast's postural control performance during a handstand may hamper other performance related aspects of handstand performance, such as task execution, handling perturbation or in cases of skill learning.

Additionally, the underlying mechanisms of the effectiveness of elastic taping in case of athletic performance of a healthy and active athlete, can yet be assumed. Athletes, coaches and therapists may use and advise elastic tape applications for several reasons, for instance due to comfort, the belief in its clinical significance and changed mechano-sensory perception. Therefore, it is still of high interest to study potential effects of elastic taping in a standardized methodological approach and in light of the requirements of the sporting event, especially in terms of varying sport specific task-demands.

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