

# The effect of low-Dye taping on hopping performance in handball players

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*Purpose:* Low-Dye taping is a useful technique for preventing foot injuries. However, the use of inextensible tape may lead to a decline in movement performance as a result of limited foot joint mobility and a change in vertical stiffness due to the passive stiffening of the tarsus and metatarsus. Therefore, the aim of the present study was to determine the effect of low-Dye taping on sport movement performance observed during a hopping task. *Methods:* The study was carried out on a group of 11 male handball players. The Myotest accelerometer was used to evaluate the effect of low-Dye taping on jumping height, ground contact time and vertical stiffness during the hopping test. Each study participant performed four series of 5 hops (hopping test): two series before low-Dye taping and two after. *Results:* No statistically significant differences were found between the values recorded before and after low-Dye taping for the variables that describe the hopping task: mean jump height, mean ground contact time and mean vertical stiffness. *Conclusions:* Low-Dye taping can be successfully used in handball players since it has a preventive effect that reduces the risk of injury to the foot and does not influence vertical stiffness or jump height to a significant extent.

*Key words:* contact time, foot torsion, quasi-stiffness, vertical stiffness

## 1. Introduction

Handball is a team sport characterized by a high number of so-called “explosive movements” performed by the player during the game. Handball players move at high velocities in different directions. The specific forms of movements (running, side stepping, running backwards) are accompanied by frequent changes of direction [24]. Apart from horizontal movement, handball players also perform jumps, both those connected with shots, passing the ball or defensive play and those aimed at blocking the shots performed by the opponent [28]. During offensive play, the jump shot is often preceded by a series of feints or a preparatory jump. Therefore, it is critical to skilfully combine all these activities and perform them one after another. The specific movements of handball players on the court

(hard indoor arena floors) generate the risk of overload to the musculoskeletal system, which, consequently, increases risk of injury. Furthermore, contact with the opponent might substantially elevate this risk [7], [24], [28]. Jørgensen [12] found that most of the injuries suffered by handball players occur in the hands and fingers (29%), feet and ankle joints (16%), and the knee joints (10%). This researcher also documented that physiotherapeutic interventions were needed in 47% of those injuries [12]. Therefore, recent years have seen the development of preventive and posttraumatic therapies oriented at maximizing the effects and minimizing the duration of convalescence.

Low-Dye taping is a useful technique for the primary and secondary prevention of foot injuries (e.g., plantar fasciitis) [21]. The technique is based on the foot torsion model, which is critical to such movements performed by an athlete as running or landing

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after a jump. In natural conditions, the above physical activities lead to forefoot pronation and tarsus supination (which are typical of foot torsion), with substantial involvement of the tibialis posterior and peroneus longus muscles. Foot torsion is responsible for maintaining the medial longitudinal arch of the foot that tends to be lowered in the case of overload to the above muscles and soft tissues of the foot [17]. Low-Dye taping is used to support the affected structures of the lower limb, which is critical to injury prevention in the foot region and provides foot stability by the application of the inextensible tape [14]. According to Radford et al. [21], one drawback of rigid foot taping is its poor durability resulting from the region of application (intensive sweating and humidity resulting from wearing socks and shoes during physical exercise). However, the adhesiveness of the tape glued on the athlete's body during training or a game was improved by the use of additional glue. Therefore, the problem of the application life becomes insignificant. Furthermore, low-Dye taping uses small amounts of material, thus reducing costs.

An adequate level of joint mobility in the lower limbs is needed to ensure top running performance. As the running velocity increases, the range of motion in the lower limb joints becomes greater. At the same time, the duration of the contact phase is reduced, whereas the flight phase is elongated. Struzik et al. [26] found that the plantar flexion and dorsal flexion movements in the ankle joint observed during running at maximum velocity should be performed over the greatest range possible. However, Brizuela et al. [2] argued that external aids (e.g., using an inextensible tape) that limit mobility in the ankle joint lead to less efficient shock absorption and are likely to limit sport movement performance. In a study by Schulze et al. [23] ankle joint mobility was found to depend on the properties of footwear. However, the ankle joint has a different function and specific nature compared to small joints in the foot region that are affected by low-Dye taping. Krell and Stefanyshyn [15] demonstrated that sprinters who had shorter running times were characterized by higher maximal rates of metatarsophalangeal extension. Therefore, limitations of the range of motion in the foot joints may also be reflected by the level of performance during a run or jumping activity. Krell and Stefanyshyn [15] suggested that kinematics of lower limbs are critical to sport movement performance. However, the contribution of each joint of the lower limb to sport movement performance remains unclear.

Handball player movements on the court involve cyclic movements of the lower limbs marked by re-

peated accelerations and decelerations. Therefore, the so-called "spring-mass model" can be useful in mapping this specific movement pattern. The model comprises a point that represents the total body mass and a spring representing the massless lower limb. During movement, lower limbs act as springs used to ensure the motion of the centre of mass. One of the variables used to describe body motion in the spring-mass model is stiffness, which is the quantitative measure of resistance to deformation. Stiffness, viewed as a ratio of the cause of the strain to the quantitative measure of strain, is described as an essential factor in the optimization of human locomotion [1], [6]. Dalleau et al. [4] argued that stiffness is related to the maximal performance of cyclic and "explosive" movements. When running or jumping, the human body absorbs the effects of external forces, while the structures responsible for this behaviour include compliant tissues (such as skeletal muscles or structures in the lower limb joints) [16]. Hobara et al. [9] expressed the views that the body with a greater level of stiffness is able to counteract the destructive forces more effectively. However, it can be presumed that both relatively high and low values of stiffness can lead to injuries of soft tissues and joints [9], [19]. Therefore, it is unclear which of the presented variables (range of motion in the lower limbs, vertical stiffness) is critical to sport movement performance and whether passive stiffening of the foot is related to the value of vertical stiffness.

The aim of the study was to determine the effect of low-Dye taping on sport movement performance observed during the hopping task. The use of an inextensible tape may lead to a decline in movement performance as a result of limiting foot joint mobility and the change in vertical stiffness due to the passive stiffening of the tarsus and metatarsus. Vertical stiffness is viewed as a ratio of changes in the value of ground reaction forces to the respective changes in the height of the centre of mass of the jumping athlete.

## 2. Materials and methods

This study examined 11 male athletes who played handball at the level of the first national league. The mean age ( $\pm$ SD) of the study participants was  $20.2 \pm 1.3$  years, body height was  $186.6 \pm 6.7$  cm, and body mass was  $83.9 \pm 12.7$  kg. The experiments were performed in a Biomechanical Analysis Laboratory (with PN-EN ISO 9001:2009 certification). The participants signed an informed written consent to participate in

the experiment during a single training session. The inclusion criteria were a certificate signed by a sports medicine physician confirming good health status to participate in competitive sports (no contraindications). Analogously, the exclusion criteria included no medical certificate and any pain in the lower limbs before or during the experiment. The research project was approved by the Senate's Research Bioethics Commission, and the procedures complied with the Declaration of Helsinki regarding human experimentation.

Each study participant performed four series of 5 hops (hopping test) according to the manual of the Myotest – performance measuring system (Sion, Switzerland). The following variables were recorded during the test: jump height, ground contact time and vertical stiffness. The hopping test was used with some simplifications that resulted from the use of the spring-mass model, which characterizes both running and hopping [1].

The experiments were preceded by a handball-specific warm-up period. The participant wore a belt with the accelerometer attached at the pelvic level. Next, the participant was asked to perform a series of 5 hops from the standing position to maximum height and with minimal time of contact with the ground. During the experiment, the participant was asked to rest their palms on the hips to exclude the effect of arm swing. Each study participant started performing a trial series after becoming familiar with the test. After the trial series, the proper research procedure began. After repeating the hopping test twice, the low-Dye taping method was used to apply tapes on the plantar region of the foot [22]. After 10 minutes of tape application (time needed for the tape to reach adequate adhesiveness to the foot and for the foot to adapt to the changing conditions), the hopping test was repeated twice again.

The Myotest Sport accelerometer (Sion, Switzerland) was used to evaluate the effect of low-Dye taping on jumping height, ground contact time and vertical stiffness during the hopping series. The 3D accelerometer allows for the measurement of acceleration during motion and under training conditions. The measurement frequency was set at 500 Hz. Further analyses used the tests with higher mean hopping heights achieved by each study participant before and after tape application. In the Myotest manual, the manufacturer did not explain how the values of individual variables are estimated. However, based on the accelerometer capabilities, one can guess that the values of jumping height and ground contact time were determined based on the duration of the flight and ground

contact phases [3], [25]. Furthermore, vertical stiffness can be evaluated using the equation described by Dalleau et al. [4] which assumes that the curve reflecting the ground reaction force versus time is a part of the sine wave:

$$K_v = \frac{m \cdot \pi \cdot (t_f + t_c)}{t_c^2 \cdot \left( \frac{t_f + t_c}{\pi} - \frac{t_c}{4} \right)}, \quad (1)$$

where  $K_v$  is vertical stiffness,  $m$  is body mass,  $t_f$  is flight time and  $t_c$  is ground contact time.

Inextensible Dream<sup>®</sup> Tape with a width of 4 cm and a length of 5 m was glued after application of Tuffner<sup>®</sup> Pre-tape spray (manufactured by Mueller<sup>®</sup>) to improve adhesiveness to the skin. The taping sequence was consistent with that described by Schulthies and Draper [22], according to the modified low-Dye taping technique. The first step was gluing of the base at the line of the heads of the metatarsal bones (I–V). Next, the octal system was used to glue the tape from the first head of the metatarsal bone on the lateral side of the calcaneus, wrapping the foot around, and, through the medial side, meeting the first head of the metatarsal bone again. The octal method was repeated twice. Foot torsion (consisting of tarsus supination and metatarsus pronation) was achieved by gluing transverse tape straps from the lateral to medial sides under the tarsus and in the reverse order in the mid-foot region. The torsion model ensured the support and extension of the medial arch of the foot. Next, the tape was glued along the longitudinal arches while wrapping the heel. Finally, the application was fixed with the tape applied analogously to the base.

Due to a relatively small number of cases ( $n = 11$ ), the significance of differences between the variables that described the hopping performance before and after low-Dye taping was evaluated by means of the Wilcoxon signed-rank test for dependent variables. The level of statistical significance was set at  $\alpha = 0.05$ .

### 3. Results

In Table 1, the mean values ( $\pm$ SD) of the variables that described the hopping performance before and after low-Dye taping are presented.

No statistically significant differences were found between the values recorded before and after low-Dye taping for the variables that described the hopping task: mean jump height, mean ground contact time and mean vertical stiffness.

Table 1. Mean values ( $\pm$ SD) of the jump height ( $h$ ), ground contact time ( $t_c$ ) and vertical stiffness ( $K_v$ ) before and after low-Dye taping

	$h$ [m]	$t_c$ [s]	$K_v$ [kN/m]
Before low-Dye taping	$0.42 \pm 0.04$	$0.24 \pm 0.09$	$21.8 \pm 11.1$
After low-Dye taping	$0.39 \pm 0.05$	$0.27 \pm 0.11$	$20.7 \pm 15.2$

## 4. Discussion

The aim of this study was to determine the effect of low-Dye taping on movement performance during the hopping task, characterized by variables such as jump height, ground contact time and vertical stiffness. No significant differences were found in the values of the above variables before and after the application. Therefore, it can be presumed that taping, which is used for the prevention of injuries in the region of the foot, does not impact sport movement performance to a significant extent during the hopping task. This lack of significant differences may have been caused by a small range of tape application, limited only to the plantar surface of the foot. With this range, the tape did not limit the motion in the joints with a relatively extended range of motion (e.g., ankle joints and metatarsophalangeal joints), which was conducive to maintaining sport movement performance. Application of inextensible tape using low-Dye taping can be successfully used in handball players since it has a preventive effect that reduces the injury risk in the foot and does not limit movements significantly.

Struzik et al. [26] documented relationships between 30 m sprint time during the maximum velocity phase and the range of motion in plantar and dorsal flexion in the ankle joint. They found that the motion of the foot with relation to the transverse axis during the maximum velocity phase in sprinting should be performed over the fullest possible range. This relationship can be attributed to the use of elastic energy released in the running stride. With the ability of tendinomuscular groups to absorb and recover the elastic energy, the energy intensifies the contraction work. Therefore, leg (or vertical) stiffness should have a positive impact on running performance [5]. Leg stiffness increases with velocity to modulate stride frequency and propulsion energy [13]. A higher range of motion in the ankle joint with respect to the transverse axis causes greater extension of the Achilles tendon, which accumulates and releases elastic energy. Obviously, the entire “spring” used during the running stride is formed by a much greater number of soft tissues, i.e.,

the skeletal muscles [6]. Furthermore, Hamner et al. [8] demonstrated that plantarflexor muscles have a key effect on running velocity. However, low-Dye taping did not limit the function of the above anatomical structures in the region of the foot.

Another cause of the absence of significant differences in the variables before and after application of the inextensible tape may be the different roles of the joints located in the region of the tarsus and metatarsus. These joints are characterized by a substantially narrower range of motion than the ankle joint with respect to the transverse axis, and it has been claimed that they perform different functions. Wang et al. [29] showed that the greatest range of motion in the tarsal region was observed for the talonavicular joint, with mean values of  $21.1 \pm 4.7^\circ$  for inversion and eversion and only  $7.4 \pm 2.8^\circ$  for the plantar and dorsal flexion. The advantage of the ranges of the motion performed with respect to the sagittal axis is likely to indicate a small contribution of tarsal joints to movement performance compared to the significant effect of the upper ankle joints, with the major component being movements with respect to the transverse axis (dorsal and plantar flexion). This advantage in the inversion and eversion motion may be more critical to the adaptation of the foot to the ground and maintaining the body in a relative equilibrium during dynamic activities such as jumping or running. The small range of motion in the tarsal and metatarsal joints with respect to the transverse axis may have contributed to the lack of significant differences in the variables that describe hopping before and after the application of low-Dye taping. According to Holmes et al. [11], adequate foot function and reduced susceptibility to injuries are determined by maintaining the foot in the region of the neutral position, likely because the tendency for greater pronation or supination in the foot reduces shock absorption and increases overload and susceptibility to injuries.

An experiment based on the use of an accelerometer cannot be directly compared to the findings of experiments based on the use of any model other than spring-mass model. Rabita et al. [20] demonstrated that the ankle joint has a critical effect on the adjustment of overall musculoskeletal stiffness, which is relatively insensitive to changes in knee or hip joint stiffness. Furthermore, Hobara et al. [10] argued that the knee joint plays a major role in energy absorption during the hopping task. Taken together, the above-mentioned data suggest the mechanisms of stiffness regulation depended on the properties of larger joints of the lower limbs. In our study, the low-Dye taping intervention concerned the small joints of the foot,

which explains the lack of significant changes in vertical stiffness after tape application. On the other hand, adding “external stiffness” in the form of a stiff plaster relieves the muscular system, allowing its stiffness (in the form of vertical stiffness) to be reduced, as joint stiffness is strongly related to the state of muscle tension. The value of joint stiffness is proportional to the square of the torque released by the muscles (muscle tension) acting on the joint [30]. The quadratic nature of this relationship means that even a small amount of relief (due to the use of the plaster) can lead to a significant change in the vertical stiffness of the jumper. This effect is likely to be especially pronounced when a plaster is used on the ankle joints.

Due to the specific selection of the research participants, which included only healthy athletes (handball players), it cannot be stated that low-Dye taping is capable of reducing pain syndromes caused by overload or injuries in the region of lower limbs. Klich et al. [14] conducted an experiment to evaluate the difference in feeling delayed onset of muscle soreness in the area of the rear tape on the lower limb after a low-Dye taping application in futsal athletes. The results obtained by these researchers showed that stimulation of the plantar surface of the foot with inextensible tape increases the pressure pain threshold, consequently reducing the delayed onset of muscle soreness, which suggests the reliability of low-Dye taping in the treatment of pain in the foot and lower limb. It is important that, in addition to the examination of the positive effect of the therapeutic method in an objective manner, the negative impacts of the procedures used should also be examined and excluded. Searching for the differences in the measures assessed in the hopping test before and after application of low-Dye taping was aimed at eliminating the risk of the negative effect of low-Dye taping on sport movement performance.

Measurements of vertical stiffness using an accelerometer did not provide insights about the ratios of stiffness in individual joints of the lower limb. It was only possible to draw conclusions based on the roughly evaluated value of the vertical stiffness that the stiffness of individual structures of the lower limb was not changed after low-Dye taping. It should be noted that due to the measurement method (which assumes that the centre of mass motion is harmonic), the values of vertical stiffness were significantly overestimated [3], [4], [27]. Therefore, this measurement offers an approximate value that can provide information only about changes in vertical stiffness. Furthermore, the stiffness determined based on the observation during motion should be viewed as quasi-stiffness, i.e., the

ability of the human body to resist external displacements while ignoring the temporal profile of the displacement [16].

Another problem was the choice of the research participants that included healthy study participants without any pain syndromes, which are often treated with low-Dye taping. Therefore, it is impossible to state whether sport movement performance would be improved in people with pain syndromes due to reductions in pain. Future research should be aimed at the group of patients who are recommended to use low-Dye taping. Despite numerous studies describing changes in the distribution of plantar pressure caused by low-Dye taping interventions during both quasi-static and dynamic exercises [17], [18], the effect of application on kinematic variables in individual joints of the lower limb (including joints in the foot) must be determined for an unequivocal evaluation of taping mechanisms.

## 5. Conclusions

Low-Dye taping, which is used for the prevention of injuries in the foot, does not significantly impact movement performance during the hopping task. The values of jump height, ground contact time and vertical stiffness remained at similar levels before and after low-Dye taping. This may be due to the small area of tape application, limited only to the plantar surface of the foot.

Low-Dye taping involves the attachment of a rigid (or susceptible) element to the limb. The stiffness of this element is an additional increase in limb stiffness. Despite this, no significant increase in vertical stiffness is observed in the examined persons. This may be due to the reduction of muscle tension. Part of the load is taken over by the “glued element”, which, in turn, reduces muscle stiffness that depends on their tension. Therefore, low-Dye taping can be successfully used in handball players, since it has a preventive effect that reduces the risk of injury to the foot and does not limit sport movement performance to a significant extent.

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