VERTICAL AND HORIZONTAL FORCES DURING CUTTING IN BASKETBALL UNDER DIFFERENT CONDITIONS

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The purpose of this study is to evaluate ground reaction force responses in professional basketball athletes while executing this sport's typical cutting maneuver with and without ankle bracing: taping, aircast-type orthosis and basketball shoes. Eight athletes were dynamically analyzed during a basketball cutting maneuver with a force platform. We collected vertical and medial-lateral forces under these three conditions and analyzed force peaks of foot contact with the ground and propulsion and growth gradient for these forces. Results show that bracing did not significantly change Fymax1 and GCFymax1; significantly reduced Fymax2 and GG Fymax2. With respect to the medial-lateral component, there were no significant differences in relation to force magnitudes between the three study conditions. However, GG Fzmax1 was significantly greater for the sport shoe condition than for the taping condition. Bracing decreased ground reaction force at some instances, but increased in others.

KEY WORDS: ground reaction force, ankle, taping, air-cast, cutting.

INTRODUCTION: For basketball players the ankle is the segment most frequently injured, and the injury having the greatest incidence is the inversion sprain. Ankle injury rate is 3.85 in 100 participations, with approximately half (45.9%) of the athletes kept away from competition for a week or more (McKay, Goldie, Payne, & Oakes, 2001).

It is common to observe athletes using prophylactic measures, such as taping, wrapping, orthoses and other measures, whether as a sprain prevention or rehabilitation. A large number of studies have investigated the usage of taping and orthoses as a prophylactic measure, usually with results defending that bracing usage reduces injuries. However, its exact mechanism of action is still not well understood. The literature describes several studies with external devices, but with contradictory results. The methods used by the authors of these conclusions are varied, ranging from kinematics and electromyographic analyses to postural oscillation and stimulation of anesthetized cutaneous receptors of the lateral ligament complex. Studies have analyzed the effects of orthoses and taping on athletic performance and some of these found that external devices impair activities such as jumping and running (Burks, Bean, Marcus, & Barker, 1991; Mckean, Bell, & Burnham, 1995). In the study by Hals, Sitler & Mattacola (2000), performance was improved in individuals with ankle instability by using a semirigid orthosis, while in the study by Verbugge (1996), it neither impaired nor improved athletic performance.

There are few studies related to ground reaction force and external ankle devices. Most of them analyzed movements that were less dynamic and not functional, not finding any differences in temporal or magnitude characteristics of GRF (Cordova, Armstrong, Rankin, & Yeasting, 1998; Hamill, Knutzen,& Bates, 1986; McIntyre, Smith, & Denninston, 1983).

The purpose of this study is to evaluate dynamic responses of ground reaction force in professional basketball players during a cutting maneuver under controlled conditions, using only sport shoes used for playing basketball and under two conditions with ankle bracing frequently used by players to increase ankle stability: taping and Air-Stirrup (Aircast Inc) orthosis.

METHODS: The sample was made up by a group of 8 athletes that had played basketball for

at least 5 years, between the ages of 17 and 25, healthy, at the time of the evaluation without musculoskeletal joint injury nor any functional or mechanical ankle instabilities. An interview was carried out with each athlete, through a questionnaire that included questions regarding anthropometrical data of each athlete, the position played, years practicing and training the sport, prior injuries and persistent sequelae, and this data was used to classify the athletes.
The athletes were evaluated by clinical and functional tests of the ankle to verify the absence of mechanical or functional instability. We chose to dynamically analyze the cutting maneuver because it is the mechanism responsible for approximately 30% of sprains (McKay, Goldie, Payne, & Oakes, 2001). This maneuver was made by athletes with and without using the two kinds of bracing and the control condition with sport shoes usually used in basketball.
The subjects were evaluated while executing a cutting maneuver on an AMTI force platform, the change in direction is executed with each athlete's dominant lower limb, under the three trial conditions.
Data from vertical and medial-lateral horizontal ground reaction force components were collected during 5 attempts, each one with a sampling frequency of 500 Hz for periods of 6 seconds. The ground reaction force variables studied were: vertical force peak (Fymax) and medial-lateral force peak (Fzmax) at foot contact with the ground (1) and during propulsion (2); Vertical and medial-lateral force growth gradient (GC Fymax and GC Fzmax) at foot contact with the ground (1) and during propulsion (2). These variables were normalized by the body weight of each subject and later filtered with a low-pass Butterworth filter with a 200 Hz cutoff frequency. Biomechanical variables studied were initially analyzed to verify the statistical data distribution through the Shapiro Wilks W test to confirm non-parametric data and therefore the three trial conditions were compared through the Kruskall-Wallis, using the Mann-Whitney test as a post hoc test. Differences with a significance level (p) lower than 0.05 were considered significant.

RESULTS AND DISCUSSION: Table 1 shows demographic variables for subjects evaluated in this study. A reasonable percentage of the subjects (50%) used external devices during games and training sessions as a way of preventing ankle sprains. Yet we observed in this study that most of the athletes (75%) had already suffered ankle sprains, and of these 66% had injured both ankles.

Table 1 Demographic variables of the basketball athletes.

VARIABLES	Age (years)	Weight (kg)	Height (m)	BMI (kg/m^2)
TEST GROUP (N=8)	22.4 ±1.7	78.8 ±9.1	1.9±0.1	21.8 ±1.7

In the sport shoe condition, the second force peak (Fymax 2) was significantly greater than the taping and Air-Cast ($p=0.0000$) conditions, but there was no difference between cutting with taping and with Air-Cast ($p > 0.05$) (table 2). As to Fymax 2 growth gradient, we observed significant differences between the three conditions ($p=0.0490$), in which the value found for the sport shoe condition was greater than the value for Air-Cast ($p=0.0020$) and taping (0.0121). Gradient values for taping and Air-Cast conditions did not show any statistical difference between them ($p=0.8778$)

Table 2 Mean and standard deviation of the vertical ground reaction force during cutting with and without ankle bracing: sport shoe, taping and Air-cast (n=8).

VARIABLES	SPORT SHOE	AIR-CAST	TAPING	P
Fymax 1 (BW)	2.04 ± 0.37	2.03 ± 0.43	2.11 ± 0.43	> 0.05
Fymax 2 (BW) *	2.02 ± 0.26*	1.44 ± 0.13*	1.50 ± 0.17 *	0.0000
Fy min (BW)	1.20 ± 0.19	1.16 ± 0.20	1.14 ± 0.25	> 0.05
GGFymax1 (BW /s)	45.64 ± 22.06	41.01 ± 16.92	44.91 ± 21.54	> 0.05
GG Fymax2 (BW /s) *	29.20 ± 27.5 *	15.85 ± 10.65 *	18.64 ± 15.59 *	0.0490

There were no significant differences with respect to force magnitudes between these three trial conditions (table 3). However, the FZmax1 growth gradient was significantly lower for the sport shoe condition than for the taping condition (p=0.0433).

Table 3 Mean and standard deviation of the horizontal ground reaction force during cutting with and without ankle bracing: sport shoe, taping and Air-cast (n=8).

VARIABLES	SPORT SHOE	AIR-CAST	TAPING	P
Fzmax 1 (BW)	1.53 ± 0.35	1.54 ± 0.39	1.54 ± 0.42	> 0.05
Fzmax 2 (BW)	0.85 ± 0.40	0.95 ± 0.26	1.00 ± 0.31	> 0.05
Fz min (BW)	0.79 ± 0.12	0.82 ± 0.21	0.81 ± 0.19	> 0.05
GG Fzmax1 (BW/s) *	27.36 ± 11.19 *	30.73 ± 11.01	35.38 ± 16.78 *	0.0433
GG Fzmax2 (BW/s)	10.75 ± 10.61	11.44 ± 11.56	14.43 ± 16.19	> 0.05

The study by Cordova, Armstrong, Rankin, & Yeasting (1998) analyzed ground reaction force in lateral displacement and found no differences between control conditions and conditions using orthoses and taping. However, in this study we found statistically significant differences in ground reaction force vertical and medial-lateral components. We observed that in the taping condition, Fymax1 at the moment of foot contact with the ground tended to be greater than in conditions with sport shoes and Air-cast, in which the growth gradient for this force tended to be greater solely in relation to Air-cast. Although taping produces greater vertical force in relation to the sport shoe, the GG value for both conditions remained similar. That is, taping increased vertical force peak, but in a proportionally greater time interval, and consequently, we are able to interpret that the excessive loading in this condition did not change. In relation to Air-cast, taping tends to produce a greater vertical force value in a smaller time interval during ground impact. The growth curve for vertical force in the taping condition has greater inclination than with Air-cast, indicating that this bracing would be exerting an improved shock-absorbing effect than the sport shoe and taping, and consequently, less loading on the more distal joints.

While analyzing the medial-lateral component of cutting, we found that with taping the growth gradient for this force at ground contact was also significantly greater than with the sport shoe (p=0.0433) and tends to be greater than with Air-cast, although medial-lateral force values were similar. This result agrees with the prior study by Cordova, Armstrong, Rankin, & Yeasting (1998), which did not find any differences in impact force peak magnitude (foot contact with the ground) in the medial-lateral component during lateral displacement similar to cutting. However, they did not analyze the time needed to reach this force peak at the moment of ground contact. The increased GG Fzmax1 in the taping condition that we observed in this study means that using this stabilizing device decreased the time to reach medial-lateral force peak. This greater growth gradient for medial-lateral force may result from a more rigid ankle, having less inversion and eversion movement amplitudes resulting from taping. This greater medial-lateral growth gradient may signify more excessive loading on the ankle and lower limb joints on a medium and long-term basis. Bracing usage would limit the time for external forces to act on the small movement amplitude available for the joint, making other foot and ankle structures absorb greater forces (Cordova, Armstrong, Rankin, & Yeasting, 1998). Furthermore, larger compressing forces might be being generated, resulting in greater injury risk.

At the propulsion phase of cutting, the sport shoe condition showed significantly greater vertical force values (FYmax2) than the taping (p=0.0000) and Air-cast (0.0000) conditions. The force growth gradient (GG FYmax2) was also significantly greater than taping (p=0.0121) and Air-cast (p=0.0020). Bracing produced smaller vertical forces in larger time intervals, that is, vertical ground reaction force peaks for impulsion are reached in less time than with taping and Air-cast, in comparison to the sport shoe. As previously analyzed, we are able to interpret that bracing might be reducing the vertical joint excessive loading at the moment of impulsion during cutting, a situation that the sport shoe was unable to carry out. This finding agrees with the study by Anderson, Sanderson, & Hennig (1995), which suggested that the using nonrigid orthosis slows the inversion movement. Therefore, the musculoskeletal system might have

more time to respond to the demands of external forces by generating less excessive loading on the foot and ankle structures.
Concerning medial-lateral force at the propulsion phase, the taping condition tends to show a greater force peak value in comparison to the Air-cast condition, and the latter is greater than the sport shoe condition. The growth gradient of taping also tended to be greater than the other two conditions. We are able to consider that when taping is used, at the moment of propulsion there are more foot movement instabilities, which is unexpected, since this bracing should serve to stabilize said medial-lateral maneuvers. .

CONCLUSIONS: At the moment the ground receives the load, taping increased the vertical force in relation to the sport shoe, but in a larger time interval, without increasing excessive ankle loading. While in relation to medial-lateral force, this reached a peak in less time, which might generate greater inversion/eversion loading on an athletes' foot. In this same maneuver, the Air-cast is exerting an improved shock-absorbing effect than the other two conditions, since it generates less vertical force in a greater time and smaller medial-lateral forces in relation to taping. As to propulsion during cutting, bracing reduced the magnitude and increased the time needed to reach vertical force peak, and therefore allowing more time for adjustments and adaptations of the muscular control system. But for medial-lateral force, taping produced greater force peaks in less time than the other two conditions, therefore generating more excessive loading during inversion/eversion.
The search to decrease medial-lateral forces would lead to an increase of other ground reaction force components, that is, an increase, for example, in vertical components of this force. This fact would cause an increase of compressive forces on the skeletal system (Cordova, Armstrong, Rankin, & Yeasting, 1998) in the medium and long-term, in injuries of the locomotor apparatus.
The prophylactic effects of preventing sprains and using it in its treatment have already been intensely described in the literature. In this study we observed that bracing generated alterations in vertical and medial-lateral ground reaction forces between taping, Air-cast and control conditions. As expected, bracing attenuated vertical or medial-lateral ground reaction force components in some instances, while on the other hand increasing others, which would lead to an increase in compressive and inversion/eversion forces on the skeletal system by restricting joint mobility. Therefore, although athletes frequently use this kind of devices, their prescription must be carefully made in view of possible risk of medium and long-term complications. The mechanism by which external ankle devices act is still unclear and more studies are needed to understand their effects on sporting activities, therefore we suggest to coaches and physical therapists to carefully prescribe bracing devices to healthy athletes.

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