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Back foot influence on dorsiflexion using three different positions of the weight bearing Lunge test

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Highlights

- First study to investigate the influence of the back-foot position during the weight bearing lunge test
- Evidence to show that back-foot position affects front foot dorsiflexion range of movement
- Clinicians should state back foot positioning to ensure consistency of assessment

Abstract

Objectives

To determine whether back foot (BF) position influences dorsiflexion range of motion (DFROM) during three different positions of the weight bearing lunge test (WBLT).

Design

Randomised, repeated measures design

Setting

Sports clubs

Participants

52 athletes participating in cutting and pivoting sports

Main Outcome measures

DFROM was obtained using a WBLT in three different BF positions: BF heel in full contact with the floor, BF heel raised off the floor and BF was non weight bearing (NWB). All measurements were obtained using three methods: inclinometer at the tibial tuberosity, toe to wall distance and goniometer angle from the lateral malleolus to the fibula head. Differences between testing positions were determined using a repeated measures one-way ANOVA and reliability analysis was performed using the Intraclass Correlation Coefficient (ICC).

Results

DFROM was statistically significantly different for all three positions of the WBLT for each measurement technique (P<.001). These results were associated with large effect sizes for all BF positions and measurement techniques. Reliability ICC values were excellent for all measurements (ICC 0.94-0.99).

Conclusions

Results show that DFROM differs depending upon the position of the BF during the WBLT. Further research is needed to establish the reproducibility of these three BF positions due to the variability observed.

Introduction

Ankle dorsiflexion range of movement (DFROM) is critical for many activities of daily living such as walking, getting up from a chair and stair climbing (Sidaway et al., 2012). Dynamic sporting movements such as decelerating, cutting, side stepping, jumping and landing all require good DFROM to allow the tibia to move forward over the foot during these movements (Crowe, Bampouras, Walker-Small, & Howe, 2020; Fong, Blackburn, Norcross, McGrath, & Padua, 2011). Restrictions of DFROM can result in insufficient tibial movement which results in the heel rising early and subsequent over pronation of the midtarsal joints. This places more stress through the forefoot causing injury (Johanson, Cooksey, Hillier, Kobbermann & Stambaugh, 2006). It has also been linked to an increase in peak landing force which results in less knee flexion and hip flexion displacement and greater knee valgus (Fong, Blackburn, Norcross, McGrath & Padua, 2011). These biomechanical changes have been identified as a risk factor for several lower limb injuries such as lateral ankle sprains (Youdas, McLean, Krause & Hollman, 2009), Achilles tendinopathy (Rabin, Kozol, Spitzer & Finestone, 2015) and anterior cruciate ligament rupture (Wahlstedt & Rasmussen-Barr 2015).

DFROM occurs at the talocrural joint (TCJ). For this movement to occur the talus must move in a posteromedial direction and the fibula must glide superiorly and rotate laterally (Brockett & Chapman, 2016). There are numerous factors which have been highlighted in the literature that can contribute to a loss of DFROM. Flexibility of the triceps surae (Young, Nix, Wholohan, Bradhurst & Reed, 2013) and arthrokinematic stiffness of the talocrual (TCJ), or subtalar joints (STJ) (Denegar et al., 2002) have been shown to contribute to a loss of DFROM. It is also seen after prolonged ankle immobilisation (Landrum, Kelln, Parente, Ingersoll & Hertel, 2013), or after injuries such as Achilles tendinopathy, Achilles rupture and lateral ankle sprains (Denegar, Hertel & Fonseca, 2002; Hertel, 2002).

DFROM is a key clinical consideration when assessing and managing lower limb injuries (Rome 1996). Previously DFROM has been measured using non weight bearing (NWB) methods of assessment but the reliability has found to be questionable and attributed to various factors such as variability of landmarks used during the assessment and force applied during the testing; intra-rater reliability ICCs 0.64-0.99; inter-rater reliability ICCs 0.29-0.81, (Moseley & Adams 1991). Several studies demonstrate that the weight bearing lunge test (WBLT) is a functional and reliable method of measuring DFROM in a weight bearing tandem stance position; intra-rater reliability ICCs=0.65-0.99; inter – rater reliability ICCs 0.80-0.99, (Powden, Hoch & Hoch, 2015). Measurements can be taken either using a tape measure to measure the distance from the toe to the wall (Hoch & McKeon, 2011), tibial angle with the use of an inclinometer (Konor, Morton Eckerson & Grindstaff, 2012) and measurement using a goniometer (Konor et al., 2012 Krause et al., 2014). The two most common positions that are used in the literature are either measurement of the front ankle with the knee flexed (Hoch & McKeon 2011) or the back ankle with the knee in full extension (Krause, Cloud, Forster, Schrank &

Hollman, 2011). Both utilise the tandem stance as originally indicated by Bennell et al., (1998) but assessing DFROM with the knee in full extension allows the clinician to assess the influence of the gastrocnemius which is not assessed when the knee is flexed.

Despite a plethora of research in this area, to date there have been no studies which have looked at the influence of the back foot (BF) and how this could affect the front foot during the WBLT. Research stipulates using a tandem stance yet, there is no standardisation of the position of the BF and whether this may affect front foot DF measurement remains unclear. This makes it difficult to compare results from studies which examine DFROM. Therefore, the purpose of this study was to determine whether BF position affects front foot DFROM during the WBLT.

Methods

Study design

The study was a randomised, repeated measures design. One examiner tested participants DRFOM for each WBLT measurement in a randomised sequence over three separate testing sessions at least 48 hours apart. During each measurement session, the participant rested for 10 minutes after the first measurement and the test sequence was repeated to gain reliability data (Konor et al., 2012). The WBLT was performed using the knee-to-wall principle described by Bennell et al., (1998) however with three BF position variations.

Participants

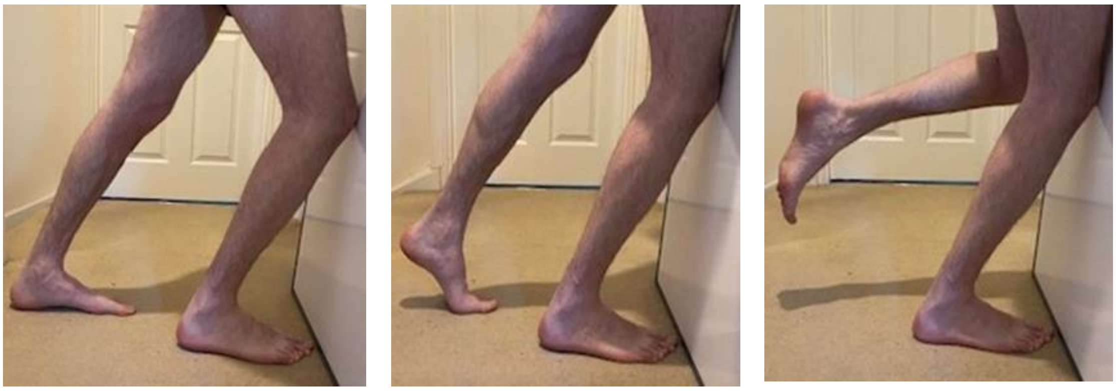
52 healthy participants (26 men/26 women, age: 27.8±7.4, Height: 173.3±9.7, weight: 77.8±16.9, Rdominant:45, Ldominant:7) who participate in cutting and pivoting sports participated in this study. Prior to testing all participants completed an injury history questionnaire to assess previous ankle injury, sport participation and leg dominance. Participants were excluded if they had a history of lower extremity surgery, any health conditions that may influence foot and ankle function, and previous history of lower extremity injury in the last six months. The participants were instructed to maintain their regular training regimens but not to exercise 48 hours prior to the day of testing. Ethical clearance was obtained by the University of Gloucestershire ethics review panel and all participants provided written informed consent for this testing.

Procedures

DFROM measurements were obtained using the weight bearing lunge test (WBLT) as described by Bennell et al., (1998) with the BF in three different positions (fig. 1).

Position 1 was where the BF remained in full contact with the floor. Position 2 was where the BF heel was raised off the floor. Position 3 was where the BF was NWB.

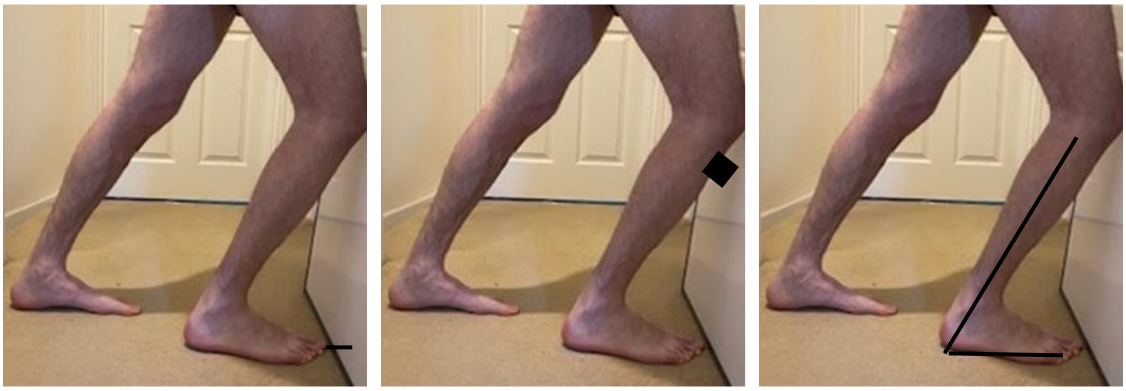
Fig.1 Position of BF during WBLT



a) BF remained in full contact with the floor b) BF heel was raised off the floor c) BF was NWB

Participants were instructed to position themselves in a tandem stance position in front of a wall. The big toe and midline of the heel of both feet were maintained perpendicular to the wall and each participant was instructed to keep the BF knee straight during each test position. Participants were asked to place their hands against the wall in front so that their hands were flat, and no gripping was allowed. Measurements were taken using three different techniques. 1) tape measure (to the nearest 0.1cm) from the big toe to the wall, 2) foot of the inclinometer placed at the tibial tuberosity with the other foot positioned on the anterior border of tibia, 3) goniometer angle from the lateral malleolus to the head of the fibula (Fig. 2). Once participants were able to maintain the position of the BF as specified in the three tests, with the knee touching the wall, the test foot was then progressed away from the wall in 1cm increments until their reach their maximum range of dorsiflexion (Hoch & McKeon 2011). The examiner ensured that front heel contact was made throughout the testing using manual contact alongside verbal instructions but did not control either pronation or supination of the foot during testing. No warmup was performed prior to testing and the testing took place in the same place using the same instruments to standardise testing conditions.

Fig. 2 WBLT measurements (Bennell et al., 1998)



a) Tape measurements from big toe to wall

b) inclinometer at tibial tibial tuberosity

c) goniometer from lateral malleolus

The WBLT was completed three times for each leg in each position and each participant completed the three different testing positions at least 48 hours apart. Prior to each testing session, participants were asked to complete another questionnaire to confirm eligibility for testing. The examiner recorded the test results from each testing session on different sheets so that previous scores did not influence the results from the last test. Test order and leg order were randomly selected prior to the first testing session.

Statistical analysis

The average of the three attempts was used for statistical analysis (Bennell et al., 1998, Rabin et al., 2015). A one- way repeated measures ANOVA (IBM SPSS, version 26) was conducted to compare DFROM for the three WBLT positions and for each measurement technique. Post hoc analysis using Bonferonni adjustment was used to determine differences between WBLT positions. Partial effect sizes (eta squared n^2) were calculated (Cohen, 1988). Reliability was calculated using the Intraclass Coefficient Calculation (ICC) (Shrout & Fleiss, 1979) and Standard error of measurement (SEM) (SEM=SD √1-ICC) for all measurements (Atkinson & Nevill, 1998). Reliability was defined as poor (ICC <50), moderate (ICC 50-to 0.75) good (ICC 0.75-0.9) and excellent (ICC <0.90) (Koo & Li, 2016).

Results

The descriptive data for measurements for DFROM for all different positions of the weight bearing lunge test are presented in Table.1. Differences between conditions were found for all methods of measurement. The data had no outliers and was normally distributed, as assessed by boxplot and Kolmogorov-Smirnov ($p > .05$), respectively. The assumption of sphericity was violated , as assessed by Mauchly's test of sphericity for all measurement techniques, except for both goniometer measurements and inclinometer measurements of the left leg (Tape measure R: X2[2]=23.02, p=.001; Tape measure L. X2[2]=21.18, P=.001, Inclinometer R: X2[2]=8.70, P=.013). Therefore, a Greenhouse-Geisser correction was applied for both tape measurements and inclinometer measurements of the right leg (tape measure R ε=.73; Tape measure L ε=.74, Inclinometer R ε=.86). DFROM was statistically significant for all three WBLT positions (Tape measure R: F(1.46,74.51)=295.57 p<.001, partial η^2=.88, Tape measure L: F(1.49,75.82)=231.62 P<.001, Partial η^2=.85, Inclinometer R:F=(1.73,87.95) P<.001, partial η^2=.57). The assumption of sphericity was not violated , as assessed by Mauchly's test of sphericity for goniometry measurements and inclinometer measurements of the left leg (goniometer R:X2[2]=5.39, p=.067), L: X X2[2]=3.27, p=.19, inclinometer L: X2[2]=3.86, p=.15). Results show that DFROM was significant between all three positions (goniometer R: F=(2,102) p<.001 Partial η^2=.33, L: F=(2,102), P<.001, Partial η^2=.41, inclinometer L: F=(2,102) P<.001, Partial η^2=.37).

Table 1. Weight Bearing Lunge Dorsiflexion Range of Motion Measurements

Test	Side	Position 1 BF remained in contact with the floor	Position 2 BF heel raised off the floor	Position 3 BF NWB
Tape Measure (cm)				

	Right	8.91±3.55*	10.42±3.42*	12.14±3.34*
	Left	9.40±3.26*	10.85±3.16*	12.47±3.16*
Goniometer (°)				
	Right	31.73±8.05*	33.97±7.37*	36.91±7.02*
	Left	33.14±8.04*	36.33±8.32*	39.94±7.63*
Inclinometer (°)				
	Right	37.29±8.47*	40.23±7.63*	44.84±7.38*
	Left	38.90±8.05*	41.59±7.88*	45.07±6.75*

*. The mean difference is significant at the 0.05 level

Post hoc analysis with a Bonferroni adjustment revealed that DFROM was statistically significantly from position 1 to position 2 for all measurements (tape measure R: M=1.51cm, 95%[1.26-1.76], P<.001, Tape measure L: M=1.44cm, 95% CI [1.14-1.75], p<.001, Goniometer R: M=2.24cm, 95% CI [0.74-3.74], P.002, goniometer L: M=3.19cm, 95%[1.41-4.98], P<.001;Inclinometer R: M=2.94cm, 95%[1.61-4.27], p<.001, inclinometer L: M=2.69cm, 95%[1.01-4.38], p<.001. Statistically significant results were also seen between position 1 to position 3 (tape measure R M=3.23, 95% CI [2.82-3.65], p<.001, L M=3.07 95% CI[1.34-1.91], P<.001, goniometer R: M=5.185 95% CI [3.19-7.18], P<.001, L: M=6.81 95% CI [4.79-8.83], P<.001, inclinometer R: M=7.55 95% CI [5.66-9.44], P<.001, L: M=6.17 95% CI [4.04-8.31], P<.001) and between position 2 and position 3 (tape measure R: M=1.72 95% CI [1.42-2.02], p<.001, L: M=1.63, 95% CI[1.34-

1.91], P<.001, goniometer R: M=2.95 95% CI [1.07-4.83], P<.001, L: M=3.62 95% CI [1.39-5.84], P<.001, inclinometer R: M=4.61 95% CI [3.03-6.19], P<.001, L: M=3.48, 95% CI [1.41-5.54] P<.001). These results demonstrate that DFROM differs depending on the BF position during the WBLT.

The within-session intra rater reliability (ICC3,1) ranged from 0.98-0.99 (tape measure), 0.97-0.98 (goniometer) and 0.94-0.98 (inclinometer) (table 2.). SEM values ranged from 0.45cm-0.81 cm for tape measure, 1.96°-2.72° for goniometer and 2.28° to 3.09° for inclinometer.

Table 2. Intraclass Correlation Coefficient (ICC) and Standard Error of measurement (SEM) for all measurements and positions of the weight bearing lunge test.

Test	SD	ICC	ICC 95% CI	SEM
Position 1				
Tape measure R (cm)	7.13	0.98	0.97-0.99	0.81
Tape measure L (cm)	6.54	0.99	0.98-0.99	0.65
Goniometer R (°)	16.00	0.98	0.98-0.99	2.26
Goniometer L (°)	15.76	0.97	0.96-0.98	2.72
Inclinometer R (°)	16.88	0.98	0.97-0.99	2.28
Inclinometer L (°)	16.07	0.97	0.94-0.98	2.78
Position 2				
Tape measure R (cm)	6.87	0.99	0.99-0.99	0.49

Tape measure L (cm)	6.32	0.99	0.99-0.99	0.45
Goniometer R (°)	14.51	0.98	0.97-0.990	2.05
Goniometer L (°)	16.38	0.98	0.97-0.99	2.31
Inclinometer R (°)	15.04	0.96	0.93-0.97	3.00
Inclinometer L (°)	15.49	0.96	0.94-0.98	3.09
Position 3				
Tape measure R (cm)	6.61	0.99	0.98-0.99	0.62
Tape measure L (cm)	6.30	0.99	0.99-0.99	0.63
Goniometer R (°)	13.90	0.98	0.97-0.99	1.96
Goniometer L (°)	15.06	0.97	0.94-0.98	2.60
Inclinometer R (°)	14.65	0.96	0.94-0.98	2.93
Inclinometer L (?)	12.65	0.94	0.90-0.96	3.09

SD (standard deviation); ICC (intra Class Correlation Coefficient); ICC 95% CI (95% confidence intervals); SEM (Standard error or measurement)

Discussion

This was the first known study to determine whether the BF position affects DFROM during the WBLT. Previously, studies have looked at the reliability of different measurement techniques of the WBLT (Bennell et al., 1998, Hoch & McKeon 2011, Powden et al., 2015) but to date no study has looked at whether variation of the BF position during the WBLT would affect DFROM. In this study a statistically significant difference was observed for distance measured depending upon back foot position ($P<.05$). Post hoc analysis indicated that there was a significant difference in DFROM for all positions of the WBLT. Position 1 and 3 ($P=<.001$), position 1 and 2 ($p<.001$) and between positions 2 and 3 ($p=<.001$). Large effect sizes were found for all measurements (Partial $\eta 2$= 0.33-0.88).

Excellent reliability (ICC>0.94) for all measurements in all three positions were found in this study. Tape measurements demonstrated higher reliability coefficients (ICC=0.98-0.99) in comparison to goniometer measurements (ICC =0.97-0.99) and inclinometer measurements (0.94-0.98). In addition, tape measurements resulted in lower measurement error (SEM= 0.45cm-0.81cm) than those found for the goniometer (SEM=1.96°-2.72°) and inclinometer (SEM=-2.28°-3.09°). These findings are consistent with those found in other studies (Bennell et al., 1998; Konor et al., 2012; Langarika-Rocafort, Emparanza, Armendi, Castellano & Calleja-Gonzalez, 2017) and suggest that reliable DFROM measurements can be taken using a tape measure, inclinometer or goniometer.

Measurements of DFROM using the different positions were comparable with other research in this area (Bennell et al., 1998; Hoch & McKeon 2011; Hall & Docherty 2017). Goniometer measurements are consistent with previously reported values of 30°-50° (Konor et al., 2012). However, the values did vary depending on the BF position (Position 1 R: 31.73±8.05, L: 33.14±8.04, Position 2 R: 33.97±7.37, L:36.33±8.32, position 3 R: 36.91±7.02, L: 39.94±7.63, Table 1.). Goniometer measurements were found to be lower than the inclinometer measurements for this study and contradicts findings from Konor et al., (2012). Reasons for the differences could be due to anatomical placement error. The examiner in this study reported difficulties in inclinometer placement on the tibial tuberosity as this left little clearance between the wall and inclinometer for those participants with DFROM below 6cm. Although intra rater reliability was found to be excellent (ICC=0.94-0.98), SEM values were calculated as 2.28°-3.09° and so the variability in measurement could be attributed to anatomical placement.

Tape measurements were slightly lower than what has been previously reported by Bennell et al., (1998) and Hoch and McKeon (2011) but is similar to those reported in Konor et al., (2012) (position 1 R: 8.91±3.55, L: 9.40±3.26, position 2 R: 10.42±3.42, L: 10.85±3.16, position 3. R: 12.14±3.34, L: 12.47±3.16). However, it is difficult to compare with other studies as they have not stipulated the BF foot position during the WBLT so therefore it is not known what position is required to compare measurements.

As stated previously, DFROM can be restricted due to previous injury (Denegar et al., 2002), tricep surae tightness (Young et al., 2013), arthrokinematic joint stiffness of the TCJ or STJ (Denegar et al., 2002) or prolonged immobilisation. It is reasonable to hypothesise that if there is a restriction of the BF DFROM then this would restrict the ability for the front foot tibia to advance over the foot, therefore reducing DFROM and would affect the measurement taken during the WBLT. In position 3 the influence of the BF is removed and therefore DFROM was found to be larger in comparison to position 1 and 2. During this position, participants are performing a single leg squat. Optimal performance of the single leg squat is described as the hips, knees and ankles being aligned in parallel with no hip rotation and the standing leg heel remaining on the ground (Kim, Kwon, Park, Jeon, & Weon, 2015). Faulty movement patterns such as medial rotation of the hip and knee valgus may affect DFROM (Dill, Begalle, Barnett, Zinder & Padua, 2014). Therefore, it is important the clinician ensures that these compensatory movement patterns do not occur when performing this position (Kim et al., 2015). Leg strength has also been shown to affect knee flexion during a single leg squat. Participants who have the strength to control the single leg squat through their abductors and quadriceps may have resulted in larger knee flexion therefore resulting in greater DF (Bailey, Selfe, & Richards, 2010). During this study participants did report that this position was the most difficult to perform as it required control and balance through one limb. It is also not an appropriate test to perform during the early stages of rehabilitation where strength, proprioception and ROM may be impaired.

Position 2 (BF heel raised off the floor) potentially reduces the effect of triceps surae tightness or TCJ stiffness. Studies have shown that elevating the heels with a wedge during a squat can increase DFROM (Johanson et al., 2006; Bell-Jenje et al., 2016) therefore, raising the heel off the floor should increase DFROM. In this study, it could be advocated that position 2 (BF heel raised off the floor) is the most suitable to test DFROM during the WBLT as you are minimising the influence of any triceps surae or joint restriction of the non-test leg on the leg you are testing. However, further research needs to be conducted to determine the influence of muscle length and joint stiffness on the BF during the WBLT and how this affects DFROM.

Position 1 requires the BF to remain in full contact with the floor. In this study the WBLT requires the back knee to be completely straight which will result in both gastrocnemius and soleus being placed under tension. Although not measured in this study, differences in ROM may have been seen if the back-knee position was also varied. A study by Baumbach et al., (2014) demonstrated a difference in DFROM with the knee bent in comparison to the knee straight, however DF was only measured in the NWB position and so it is not known whether the same results would be seen if knee position was varied during the WBLT.

This study is not without its limitations. The sample of participants used in this study took part in sport and therefore, the results cannot be generalised to a non-sporting population. However, the findings are in agreement with other DFROM studies (Bennell et al., 1998; Hoch & McKeon, 2011; Hoch, Staton, & McKeon, 2011; Konor et al., 2012; Hoch, Farwell, Gaven, & Weinhandl, 2015). Another limitation to the study is that there was no standardisation of the distance between the BF and the front foot, therefore, it is not known to what extent this would affect DFROM in positions 1 and 2. The examiner also reported difficulties in inclinometer placement when testing those participants with less than 6cm DFROM as this may leave little clearance between the wall and the inclinometer. By placing the inclinometer 15cm away from the tibial tuberosity on the anterior border of the tibia there is no obstruction and therefore this placement would be suggested for future studies (Bennell et al., 1998; Hall & Docherty, 2017)

Conclusion

Results show that whilst performing the WBLT, DFROM differs during all three different positions of the WBLT. The researcher and practitioner should standardise and declare the test method used to ensure consistency and reproducibility. Joint stiffness, triceps surae muscle tightness, hip strength and proprioception are important considerations for test position selection. There is a plethora of research on the WBLT but as it is not known what BF position is used it is very difficult to compare studies and therefore future research should stipulate BF position when carrying out this measurement. Moreover, there is a need for a standardised approach to the WBLT so that DFROM is not biased by BF placement.

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