# AGE BASED MECHANICS OF MAXIMAL JUMP PERFORMANCE IN ENDURANCE ATHLETES

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The purpose of this study was to explore age based maximal jump performance responses, and the underlying kinetic contributions of endurance athletes. Master athletes (aged 60 to 68 years) jumped significantly lower than the younger athletes (aged 26 to 32 years), which was evidenced by a lower vertical velocity at take off by 0.79 $m \cdot s^{-1}$. The significant positive correlation of lower body stiffness with age was mainly attributed to increased knee stiffness from 0.54 to 1.43 x $10^{-2}$ ($^{o-1}$) for the younger to the master athletes, respectively. Exploring the knee moment associated with joint stiffness revealed that the change in knee moment in the eccentric phase was comparable between the groups and was not correlated with age. Therefore, the increased knee stiffness with age may be attributed to the restricted knee flexion in the eccentric phase.

**KEY WORDS:** lower body stiffness, joint stiffness, joint kinetics.

**INTRODUCTION**: Maximal jump performance is dependent upon the impulse generated when in contact with the ground. As a result of ageing it is possible that the underpinning mechanics contributing to maximising force production and optimising ground contact time are compromised, which has potentially detrimental effects on dynamic performance. A significantly higher jump performance of 0.12 m has been reported for young inactive males when compared to older participants (Wang, 2008). The reduced lower limb kinetics demonstrated by the older participants was considered the main contributing factors to an inferior jump performance. Wang (2008) subsequently recommended that older individuals should perform exercises that utilize the stretch shortening cycle as a preventative mechanism to changes in dynamic motion associated with ageing. Dowling and Vamos (1993) suggested that the energy stored during the eccentric stretching of the countermovement must be transported quickly in the concentric phase. More recently, Cormie et al. (2010) reported that an enhanced concentric phase when jumping is 'heavily dependent on the conditions involved' within the eccentric phase.

The exploration of the local-joint mechanics within each phase of a jump can increase the understanding of the mechanisms that affect performance. Ruan and Li (2008) suggested that a vertical jump using an approach run-in required a greater contribution from the peak knee moment when compared to the ankle and the hip. Wang (2008) similarly reported that the contributing factor to the reduced height jumped by older, inactive participants was the achievement of a significantly lower knee moment at the bottom of the countermovement compared to the younger participants. In an earlier study examining the jump performance of young runners, Chelly and Denis (2001) suggested a potentially important contribution of high leg stiffness to superior dynamic performance. Although Wang (2008) later suggested that leg and hip stiffness were similar between older and younger participants, knee stiffness was found to decrease with age and concluded the joint's reduced extensor moment was a contributing factor to knee stiffness and jump performance.

For endurance athletes a functional insight can be gained on an athlete's sub maximal running performance when their mechanics are explored under maximal conditions such as performing a maximal vertical jump (Chelly and Denis, 2001). Maximal jump rebounds have been investigated to assess leg stiffness and its mechanical affects on running performance for young runners (Chelly and Denis, 2001). The aim of this study was to explore the underlying local-body kinetic contributions to age based maximal jump performance in endurance athletes. The understanding of the age based facilitation of local-body mechanics to jump performance can be applied to endurance athletes' training in an attempt to minimise their decline in performance with age.

**METHODS:** Biomechanical data were collected for 24 male participants, who were county standard endurance athletes. The athletes were assigned to distinct age based categories; 26 to 32 years (S32, N = 8), 50 to 54 years (M50, N = 10) and 60 to 68 years (M60+, N = 6). Each athlete performed 10 jump trials from a hurdle step approach, into a two-footed landing on a force plate, followed immediately by a maximal vertical jump for height. The arm motion was controlled by placing the hands on the hips.

Three dimensional coordinate data were collected for 36 reflective passive markers using a VICON 612 (Vicon™, Oxford UK) nine camera infra-red system (sample rate: 120 Hz). A force plate (Kistler™, Switzerland, 9281C) was used to obtain simultaneous ground reaction forces at a sample rate of 1080 Hz. The x, y and z coordinate time histories for each marker were later smoothed using Woltring's cross-validated quintic spline routine (MSE = 15 mm$^2$). The spatial model developed by Davis et al. (1991) was used in conjunction with an upper body model (Vicon$^{TM}$, Oxford UK, PlugInGait) to locate the sagittal plane coordinates for the ankle, knee and hip joint centres and the centre of mass (*CM*).

The jump trial with the greatest vertical velocity of the *CM* at take off ($V_v$*@takeoff*) was identified for each athlete and considered representative of the athlete's maximal jumping performance. The performance of each jump was quantified further by the contact time with the force plate and vertical force at the end of the countermovement ($F_v$*@bsq*). Local-body kinetic measures examined at the end of the countermovement included ankle, knee and hip moments. The changes in lower body (McMahon and Cheng, 1990) ankle, knee and hip stiffness (Butler et al., 2003) from initial contact with the ground to the end of the countermovement (eccentric phase) were explored. All kinetic measures were normalised to body weight (BW) and leg length except for $F_v$*@bsq* which was normalised to BW, only.

A one-way analysis of variance test was conducted to determine significant differences in the performance and local-body kinetic measures of the age based groups. Salo et al. (2011) reported that athlete-specific strategies can be adopted to achieve maximal performance outcomes and further insight can be revealed through individual rather than group-based analysis. Therefore, a Pearson's product moment correlation coefficient was used to examine the association between an athlete's chronological age and jump mechanics.

**RESULTS:** The significant correlation ($p<0.05$) with age for $V_v$*@takeoff* ($r=0.67$), contact time ($r=0.60$) and $F_v$*@bsq* ($r=0.53$) are illustrated in Figure 1. The mean $V_v$*@takeoff* for each group was 1.87 m·s$^{-1}$ (S32), 1.54 m·s$^{-1}$ (M50) and 1.08 m·s$^{-1}$ (M60+) where there was significant difference ($p<0.05$) between the S32 and M60+ groups. There was a 31% significantly different ($p<0.05$) contact time between S32 and M60+. Although $F_v$*@bsq* was positively correlated with age $F_v$*@bsq* was similar between the age based groups.

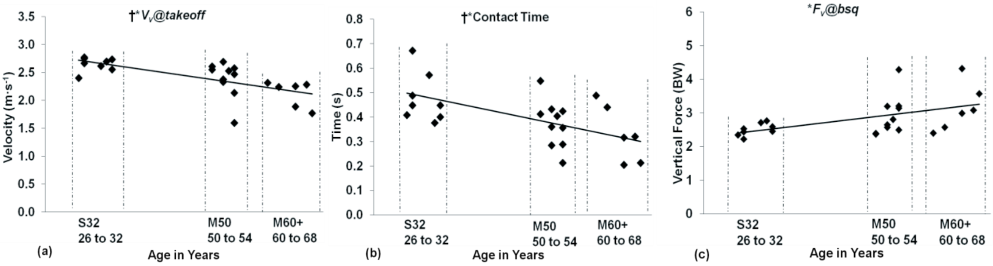

**Figure 1: The correlation between athlete age and $V_v$*@takeoff* (a), *CT* (b) & $F_v$*@bsq* (c).** (**†** indicates a significant difference ($p<0.05$) between S32 and M60+ and * indicates a significant correlation ($p<0.05$) with age).

Figure 2a illustrates the significant correlation ($p<0.05$) with age ($r=0.57$) for lower body stiffness, which was supported by the oldest athlete's stiffness being 156% greater than the youngest athlete. The lower body stiffness was 78% greater for M50 compared to the S32 group ($p<0.05$). The normalised ankle moment and knee stiffness (Figure 2b and 2c) were the only joint kinetics measured that were significantly correlated ($p<0.05$, positively) with age ($r=0.39$). S32 generating a normalised ankle moment of 0.26 and knee stiffness of 0.54 x $10^{-2}$ ($^{o-1}$) compared to 0.33 and 1.43 x $10^{-2}$ ($^{o-1}$), respectively, for M60+. No significant differences were found for both measures between the groups.

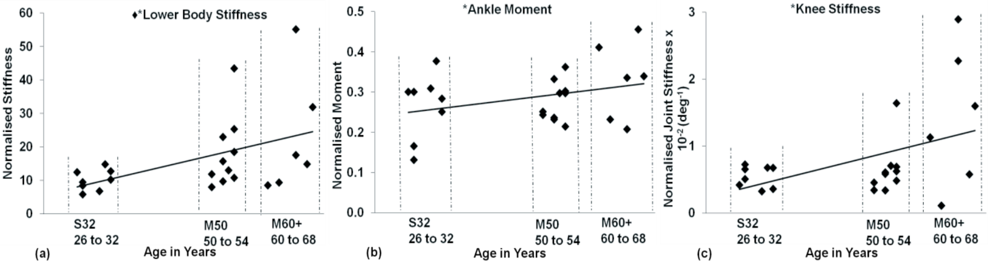

**Figure 2: The correlation between athlete age and lower body stiffness (a), normalised ankle moment (b) and knee stiffness (c).** (♦ indicate a significant difference ($p<0.05$) between S32 and M50 and * indicate a significant correlation ($p<0.05$) with age).

**DISCUSSION:** The aim of this study was to explore the age related maximal jump performance characteristics and to elucidate the underlying mechanics of master athletes' jumping. The significantly reduced $V_v$*@takeoff* of 0.79 m·s$^{-1}$ observed by M60+ and the correlation with age demonstrated a decline in jump performance with age, which could be partially explained by the shorter contact time recorded for the older athletes. An increased contact time is desirable to optimise jump impulse (Read and Cisar, 2001) but not at the expense of increasing the eccentric phase since the stretch shortening cycle would be compromised. Although, an age based decline in performance was found, the positive correlation for $F_v$*@bsq* with age demonstrated that the older the athlete, the greater the force at the time of amortization. Potentially the utilisation of the stored elastic energy during the eccentric phase would be enhanced due to a quick amortization in an attempt to maintain jump performance with age. Doherty (2003) reported a reduction in maximal strength with age as a function of muscle mass atrophy, which was attributed to a reduction in motor neurons and skeletal muscle mass. However, Tarpenning et al.'s (2004) found that the preservation of the fibre morphology with age could be attributed to athletes with 'extensive exercise histories.' The $F_v$*@bsq* produced by the older athletes may therefore be explained by the master athletes' training regime. A criterion for recruitment to this study was that the athletes performed two interval (above lactate threshold) running session per week and had been competing for an athletic club for more than five years. As a result, it was observed that the older athletes' concentric strength at the bottom of the squat had remained intact or even increased with age when compared to the younger athletes.

The decrease in jump performance of the older athletes compared to the younger athletes could be attributed to lower body stiffness which increased with age. Laffaye et al. (2005) reported that an increase in lower body stiffness, as a result of a decrease in lower body flexion, was associated with lower jump heights performed by athletes from five different exercise backgrounds. However, for the master athletes in the current study the increased stiffness was partially caused by the increase in the force at the end of the countermovement ($F_v$*@bsq*).

To enhance the understanding of the mechanisms that affect performance the analysis of the local-joint mechanics within each phase of a jump is beneficial. The normalised ankle moment increased with age although the ankle stiffness was unrelated to age. However, knee stiffness was positively correlated with age which concurs with Wang (2008) who reported increased knee joint stiffness in the older participants which contributed to an increase in lower body stiffness and an inferior jump performance compared to younger participants. The knee moment at the end of the countermovement was uncorrelated with age therefore the greater knee stiffness of the older athletes was a function of a decrease in the knee flexion in the eccentric phase. Therefore for the endurance-based athletes the increased lower body stiffness with age was partially explained by the increased knee stiffness, which was due to inhibited knee flexion in the eccentric phase of the countermovement jump.

**CONCLUSION:** When performing a depth jump for maximal height, $V_v$*@takeoff* decreased with age, which was attributed to the reduction in contact time demonstrated by the older athletes. Higher knee stiffness values that occurred with an increase in age were a result of the reduction in knee flexion since the knee extensor moments. The knee joint's musculo-tendon unit may become less pliable with age and restrict the amount of flexion in the eccentric phase of the countermovement of dynamic jumps. The application of the findings to master athletes' training is that training should be characterised by dynamic knee flexion and extension activities. The exploration of sub maximal dynamic activities performed by master athletes would further the mechanical understanding of age based changes to endurance athletes' performance.

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Vicon™, UK, Kistler™, Switzerland, master athletes