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How is jump performance affected in male athletes when completed with a visual impairment?

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Abstract

Significance: High, long, and triple jump athletic events may need to consider whether it is appropriate to group vision impaired athletes in the same classification with loss of different visual functions and a greater emphasis may need to be placed on the visual field within the current classification system used.

Purpose: Athletes with vision impairment (VI) are grouped, based upon their visual function, into one of three different classes (B1, B2 and B3; B1 most severe). Athletes in class B2 have loss in visual acuity (VA, range 1.50-2.60logMAR), or visual field (VF, constricted to a diameter of <10deg). The current study investigated how loss of different visual function (VA or VF) within the same class impacts jumping performance, a fundamental component in long, triple, and high jump athletic events.

Methods: 10 sub-elite male athletes (age 21.6±0.96yrs, height 178.8±2.97cm, mass 82.2±10.58kg) with normal vision who participate in athletics were recruited. Participants completed drop jumps in four vision conditions; habitual vision condition (Full), VA no better than 1.60logMAR (B2-VA), VF restricted to <10deg (B2-VF) and VA no better than 1.30logMAR (B3-VA).

Results: Meaningful differences were observed between Full and B2-VF condition. Following re-bound, vertical velocity at take-off was highest in Full (2.84±0.35m.s^{-1}, 95%CI: 2.68—2.99m.s^{-1}) and was lowest in B2-VF condition (20% reduction, 2.32±0.29m.s^{-1}, 95%CI: 2.16—2.48m.s^{-1}). Peak vertical jump height was highest in Full (0.42±0.10m, 95%CI: 0.38—0.46m) and reduced by 40% in B2-VF (0.28±0.07m, 95%CI: 0.24—0.32m). Minimal differences were found between Full and B2-VA, or B3-VA conditions.

Conclusion: Jump performance is compromised in athletes with simulated VI. However, decrements in performance appear specific to those with severely constricted VF. Those with reduced VA (in B2-VA and B3-VA classes) appear to produce performance comparable to those with normal vision.

Key words: jumping, Drop jump, vision impairment classification, visual field, visual acuity

Participation in athletics (the term used to describe running, throwing, and jumping sporting events) for visually impaired (VI) athletes is possible due to permitted adaptions within an event. Whilst specific adaptions are dependent upon the athlete's level of sight loss, they can include the support of a guide-runner, acoustic assistance (to initially orientate the athlete and/or provide signals during the event) and modification of the facility (e.g., paint, chalk, cones or flags) to allow the athlete to more clearly identify key features in the environment (e.g., take-off board in the long jump,[1]).

Several athletic events judge performance against the distance or height jumped; the long jump (currently included in the Paralympic games), the high jump and triple jump (not currently included in the Paralympic games but competitive events for VI athletes still occur). Crucial for successful performance in these events is the ability to develop lower limb explosive muscular power; the athlete who generates the greatest power has the potential to jump higher or further than their opponent. Plyometric exercises are a commonly used type of activity in the development of lower limb power and involve repeated, rapid, eccentric and concentric movements such as jumping and rebounding. Both the drop jump and countermovement jump are techniques commonly used in plyometric exercises to both evaluate and train lower limb muscular power.[2] However, since mechanical output is greater in drop jumps compared to countermovement jumps, it provides a greater training stimulus for athletes.[3] The drop jump (Figure 1) requires the athlete to drop from a designated height and then immediately perform an explosive vertical jump.[4] Through the individual dropping onto either a force plate or pressure mat, it is possible to ascertain key performance measures which evaluate jumping performance.

****FIGURE 1 HERE****

The traditional measure of evaluating drop jump performance records (following rebounding off the floor) peak vertical-jump height.[5] However, peak jump height is influenced by the time spent in contact with the ground; providing a longer time period to either increase the magnitude, or duration of vertical force application to generate a higher vertical velocity at take-off and achieve a greater peak jump height.[6] Therefore, since the reactive strength index (RSI) normalizes jump height to ground contact time, this may be a more appropriate measure of drop jump performance when the jumping task involves an eccentric component.[5] The maximal vertical force generated during the time spent in contact with the floor (i.e., Power) is also a key measure used in the evaluation of the vertical jump.[7]

An individual's level of vision likely impacts their jumping performance, especially when required to initially land before rebounding and jumping upwards. When completing drop landings without vision, previous research highlighted an absence in the pre-activation of lower limb musculature (this typically occurs ~200ms prior to contact,[8]) and altered landing mechanics to attenuate the impact forces.[9] The degradation as opposed to absence of vision also impacts pre-activation of the lower limb musculature and landing mechanics [10] (specific detail regarding degradation of vision not stated). When stepping down (as opposed to dropping) onto a lower level, adaptations in landing behaviour have also been observed when vision is blurred [11] or peripheral vision is occluded [12] which resulted in landing behaviour being modulated in a manner consistent with individuals being uncertain regarding precise floor height and subsequently being unable to 'fine tune' landing behaviour.[12] The implications of these findings suggest that when landing, compared to normal sighted individuals, those with degraded vision will be disadvantaged in their ability to attenuate the impact forces and subsequent generation of vertical force to propel upwards; jumping performance will be compromised.

The current system of classification in sports for athletes with VI is performed using two tests of visual function, visual acuity (VA) and visual fields (VF). VA assesses the resolution of central vision through the ability to read high contrast letters of decreasing size. VF assesses the extent and / or sensitivity of vision away from central fixation. At present, most para sports use the same visual function criteria to allow entry into VI sport and into classes within a sport, regardless of the sport or its visual requirements, although it is now a requirement for sports to produce an evidence-based, sport-specific classification system. There are currently 3 standard classes within VI sports. Athletes in class B1 (most severe VI) have VA <2.60 logMAR. Athletes in B2 have VA in the range 1.50 to 2.60 logMAR, and / or VF constricted to a diameter of <10 deg. Athletes in B3 have VA in the range 1.00 to >1.50 logMAR, and / or VF constricted to a diameter of <40 deg. The VF diameter is defined along the axis that passes through fixation that gives the maximum extent of VF that can be seen with a stimulus of 10 dB brightness.

Currently, within athletics, athletes with loss of different visual function such as VA or VF compete in the same class. It remains unclear how this approach to grouping athletes within VI sport impacts jumping performance. This is of particular relevance to long jump, high jump, and triple jump athletic events. Sport-specific evidence-based classification criteria needs to establish the visual function criteria for inclusion within a VI adapted version of a sport (the minimum impairment criteria (MIC)), guided by the level of function that impairs performance in the sighted version of the sport.[13] Criteria for assigning eligible athletes to different classes within the sport, or alternatively the evidence for the provision of only a single class within the sport, are also needed, guided by whether performance in the adapted version of the sport varies with level of function. The aim of the current study was to assess jumping performance in healthy visual normal athletes when completing drop jumps under simulated classes of VI with either loss in VA or VF and compare performance to their habitual vision. Whilst it is recognised that the long jump, high jump, and triple jump all contain a run-up prior to jumping, the run-up was excluded to isolate the impact of VI on jump performance only. Due to the role of vision in mediating pre-contact and initial landing behaviour, we hypothesise that the reduction in vision will negatively impact drop jump performance. What remains unclear, however, is whether performance differences will exist when athletes have loss of different visual function (VA or VF) but grouped within the same classification.

Methods

Participants

10 male participants (age 21.6±0.96yrs, height 178.8±2.97cm, mass 82.2±10.58kg) who represented their university in athletics and had experience of completing drop jumps as part of their regular training participated. Each participant provided written consent. The tenets of the Declaration of Helsinki were observed, and ethical approval for the study was received from Anglia Ruskin University Research Ethics Panel.

Eligibility criteria required participants to have normal vision assessed through the following visual assessments. A minimum distance VA of 0.00 logMAR (6/6 Snellen equivalent), measured at 4m with an Early Treatment Diabetic Retinopathy Study (ETDRS) chart externally illuminated to approximately 200 lux. A minimum depth perception of 40 seconds of arc, measured using the graded circles test within the Titmus stereo fly test (Stereo Optical Co., Chicago, USA). VF extent of 60 deg eccentricity, when measured using the Bjerrum Tangent Screen Test (Sussex Vision, UK), see testing details below.

Vision conditions

Participants were required to complete drop jumps (protocol below) in all four vision conditions; habitual vision condition, two vision conditions which reduced VA and one condition which reduced VF. VF was reduced though wearing Visual Impairment North England (V.I.N.E) Tunnel Vision specs (North Shields, England, UK). The Tunnel Vision specs contained small pin-sized holes in the centre, for each eye to view through, permitting view from the central VF but occluding the entirety of the peripheral VF; all participants confirmed seeing single as opposed to double when viewing through the Tunnel Vision specs. Cambridge simulation glasses [14] were used to reduce high-contrast VA and contrast sensitivity. The simulation glasses create light scatter and through wearing multiple pairs, can create varying levels of VI; 1 pair of 'level 1' glasses reduces vision by ~0.08 logMAR, whereas 1 pair of 'level 2' glasses reduces vision by ~0.16 logMAR.[14] The following VI categories were used:

VI category 'B2-VA': pairs of sim-specs were worn by participants (using a combination of Level 1 and 2 glasses) until they could only read (at best) the top line of 2 different 4 m ETDRS charts from 1 meter. This resulted in VA no better than 1.60 logMAR, which was the poorest VA that could be measured using an EDTRS chart. Athletes in B2 have VA in the range 1.50-2.60 logMAR.

VI category 'B2-VF': VF extent for each participant when wearing the Tunnel Vision specs was measured binocularly using the Bjerrum Tangent Screen Test. Whilst wearing the specs, participants were seated 1m from the screen with the eyes parallel to a central white fixation spot (presented against a black background), which they were instructed to focus on, keeping their head still, for the duration of the test. During the test, participants were asked to confirm when a second white spot first became visible. The second spot was attached to thin black wooden dowel with a 3 mm diameter white spot located at the distal end of the dowel. During the test, the second white spot was moved (by the researcher) slowly from the edge of the screen towards the central white spot (non-seeing to seeing). Once participants reported seeing the second white spot, the eccentricity from the central point was recorded. This was completed at the four vertical and horizontal meridians in a randomised order. An average of all 4 points were taken to calculate an average VF extent. The Tunnel Vision specs restricted the visual field to a 3 mm white target viewed 1m from the tangent screen (used at 1 m to evaluate the central 30 deg of visual field, 3/1000W) to <10 deg (range 5-9 deg). VI athletes classified in B2 due to their VF are required to have VF <10 deg.

VI category 'B3-VA': using a similar approach to that outlined in B1, sim-specs were worn by participants until they could only read the top line of 2 different 4 m ETDRS charts from 2 meters. This resulted in VA no better than 1.30 logMAR. VI athletes in class B3 have VA in the range 1.00 to >1.50 logMAR; see table 1 for each participant's VA and VF score for the three simulated vision impairment conditions.

****TABLE 1 HERE****

Drop jump protocol

Following the completion of a standardized 15-minute warm up (habitual vision condition) which included a range of dynamic and static stretches, in addition to pulse raising activities, participants were pseudo-randomly assigned all 4 vision conditions. In the three simulated VI conditions, prior to collecting any drop jump data, participants were encouraged to walk around the lab and become accustomed to the fitting of the various specs. No practice drop jumps were permitted.

Research has investigated the most suitable drop jump height to use in plyometric training, with ranges between 12-110 cm (for a review see [15]). However, with excessive joint loadings when landing from greater heights, optimal drop jump height has been reported to range between 40-60 cm (e.g.,[16]). The current study required participants to complete drop jumps at heights of 30, 40, 50 and 60 cm (YORK, stackable Plyo box, Strength Warehouse, USA). Each participant completed a drop jump, progressing from the lowest to highest drop height and completed all jumps within a vision condition before progressing to the next vision condition. A minimum of 30 seconds was given between jumps to delay the effects of muscle soreness.[17]

To reduce learning from somatosensory and/or proprioceptive feedback received by stepping directly up on to the block, starting position was instead attained by asking participants to walk up to the block from approximately 3 m away, using a number of 'stepping stones' which randomly varied in height from trial to trial.[12] Drop jumps were performed onto a floor sunk force plate (Kistler, Winterthur, Switzerland) measuring 600x400 mm, sampling at 1000 Hz and collected in Kistler Measurement, Analysis and Reporting Software (MARS, v. MARS, v.2.0.0.0001, Kistler Instruments, Hampshire, UK). The following same drop jump instructions were given to each participant (c.f.,[6]).

Participants were instructed to ensure their hands remained on the hips throughout the action (to isolate the contribution of the upper extremities to jump performance). After aligning the feet to the edge of the upper level and given the instruction to initiate the jump, participants dropped as opposed to jumped (controlling centre of mass drop height) from the box and were required to adopt a 2 footed landing on the lower level and in the rebound, aim to minimize contact time and maximize jump height. Participants were required to ensure they landed with both feet on the force plate after completing the jump. Any trials not completed in this manner were disregarded and repeated.

Dependant variables

Undertaking the residual analysis technique outlined by Winter [18] a Butterworth low pass filter was applied (threshold of 10 Hz) to remove any signal noise within the raw force data, prior to exporting into Microsoft Excel to calculate the following dependant variables;

1. *Vertical velocity at take*-off (m.s^{-1}): calculated through the integral of vertical force over time (i.e., impulse) which changes the momentum of the body.

$$\int_{t_1}^{t_{to}} F_{GRF}\ dt - \int_{t_1}^{t_{to}} mg\ dt = m\,v_{to}$$

Where the vertical velocity at take-off (v_{to}) was calculated through integration of the vertical ground reaction force (F_{GRF}) during the time period in contact with the ground (dt) subtracted from the weight (mg) of the athlete during the time period in contact with the ground (dt,[19]).

2. *Peak vertical Jump Height (m)*:

$$Peak\ vetical\ jump\ height = \frac{{v_{to}}^2}{2g}$$

Where v_{to} equals the vertical velocity of take-off and g is the value of acceleration due to gravity.

3. *Contact time (sec)*:

Time when the individual was in contact with the ground (threshold for contact set at ≥10N) after landing from the drop jump prior to rebounding and jumping upwards.

4. *Reactive Strength Index (RSI)*:

$$\frac{Peak\ vertical\ jump\ height}{contact\ time}$$

5. *Power (W)*

$$Peak\ F_{GRF}\ x\ v_{to}$$

Peak vertical ground reaction force (Peak F_{GRF}) prior to take-off, multiplied by the vertical velocity at take-off (v_{to}).

Statistical Analysis

Data were analysed using IBM SPSS version 26 to provide 95% Confidence Intervals (CI) for upper and lower bounds in each vision and drop jump height condition.

Results

Contact time

Collapsed across all drop heights, contact time was shortest in Full (0.40±0.10sec, 95% CI: 0.31—0.48sec) compared to all other vision conditions (table 2). The longest contact time occurred in B2-VF condition (0.50±0.18sec, 95% CI: 0.42—0.59sec) and was 24% longer than Full. Contact time in B2-VA condition (0.43±0.13sec, 95% CI: 0.35—0.51sec) was 8% longer than Full and in B3-VA condition (0.41±0.12sec, 95% CI: 0.33—0.49sec) was 3% longer than Full.

Across all vision conditions, contact time increased as drop height increased (table 2). Contact time was shortest in 30cm drop heights (0.43±0.14sec, 95% CI: 0.39—0.47sec), followed by 40cm (0.43±0.13sec, 95% CI: 0.39—0.47sec), 50cm drop heights (0.44±0.12sec, 95% CI: 0.40—0.48sec) and finally 60cm drop heights (0.45±0.14sec, 95% CI: 0.39—0.50sec).

Vertical velocity at take-off

Across all drop jump height conditions, vertical velocity at take-off was highest in Full vision (2.84±0.35m.s^{-1}, 95% CI: 2.68—2.99m.s^{-1}) compared to all other vision conditions (figure 2, table 2). Compared to Full vision condition, the largest reduction in take-off velocity was observed in B2-VF vision condition (20% reduction, 2.32±0.29m.s^{-1}, 95% CI: 2.16—2.48m.s^{-1}) with smaller differences in B2-VA (8% reduction, 2.62±0.29m.s^{-1}, 95% CI: 2.46—2.78m.s^{-1}) and B3-VA (5% reduction, 2.69±0.31m.s^{-1}, 95% CI: 2.53—2.85 m.s^{-1}) conditions.

Across all vision conditions, vertical velocity at take-off increased as drop height increased (table 2) with noticeable differences observed in 60cm drop heights (2.77±0.35m.s^{-1}, 95% CI: 2.68—2.85m.s^{-1}) compared to 30cm (2.42±0.36m.s^{-1}, 95% CI: 2.31—2.52m.s^{-1}) and 40cm drop heights (2.57±0.32m.s^{-1}, 95% CI: 2.48—2.66m.s^{-1}). There was also a noticeable difference in 50cm (2.71±0.32m.s^{-1}, 95% CI: 2.62—2.79m.s^{-1}) compared to 30cm drops.

Peak vertical Jump Height

Collapsed across all drop heights, peak vertical jump height was highest in Full (0.42±0.10m, 95% CI: 0.38—0.46m) compared to all other vision conditions (figure 2, table 2). Jump height was 40% lower in B2-VF (0.28±0.07m, 95% CI: 0.24—0.32m) 16% lower in B2-VA condition (0.35±0.08m, 95% CI: 0.31—0.40m) and 11% lower in B3-VA (0.38±0.08m, 95% CI: 0.33—0.42m) compared to Full vision condition.

Across all vision conditions, peak jump height increased as drop height increased (table 2) with noticeable differences observed in 60cm drop heights (0.40±0.10m, 95% CI: 0.37—0.42m) compared to 30cm (0.31±0.09m, 95% CI: 0.28—0.33m) and 40cm drop heights (0.34±0.08m, 95% CI: 0.32—0.37m). There was also a noticeable difference in 50cm (0.38±0.09m, 95% CI: 0.35—0.40m) compared to 30cm drops.

RSI

Collapsed across all drop heights, RSI was highest in Full (1.18±0.26, 95% CI: 1.02—1.35) compared to all other vision conditions (figure 2, table 2). The largest reduction in RSI occurred in B2-VF condition (0.84±0.18, 95% CI: 0.68—1.00) and was 34% lower compared to Full vision condition. RSI in B2-VA condition (1.05±0.27, 95% CI: 0.89—1.21) was 12% lower than Full and in B3-VA condition (1.13±0.31, 95% CI: 0.97—1.29) was 4% lower than Full.

Across all vision conditions, RSI increased as drop height increased (table 2). RSI was lowest in 30cm drop heights (1.04±0.32, 95% CI: 0.95—1.13), followed by 40cm (1.05±0.30, 95% CI: 0.96—1.14), 50cm drop heights (1.06±0.28, 95% CI: 0.98—1.15) and finally 60cm drop heights (1.06±0.27, 95% CI: 0.98—1.13).

Power

Collapsed across all drop heights, Power was largest in Full (2322±485W, 95% CI: 2052—2593W) compared to all other vision conditions (figure 2, table 2). The largest reduction in power occurred in B2-VF condition (1892±375W, 95% CI: 1622—2162W) and was 20% lower than Full. Power in B2-VA vision condition (2143±429W, 95% CI: 1873—2414W) was 12% lower than Full and in B3-VA condition (2201±451W, 95% CI: 1931—2472W) was 5% lower than Full.

Across all vision conditions, Power increased as drop height increased (table 2). Power was lowest in 30cm drop heights (1979±443W, 95% CI: 1841—2117W), followed by 40cm (2102±440W, 95% CI: 1963—2242W), 50cm drop heights (2216±465W, 95% CI: 2070—2362W) and finally 60cm drop heights (2261±457W, 95% CI: 2122—2401W).

****FIGURE 2 & TABLE 2 HERE****

Discussion

The current system of classification in sports for athletes with VI uses their visual function to group into one of three different classes. Within classes B2 and B3, athletes are grouped based on different visual function, either VA or VF. In class B2, athletes have VA in the range 1.50 to 2.60 logMAR and/or VF constricted to a diameter of <10 deg, and in B3 have VA in the range 1.00 to >1.50 logMAR and/or VF constricted to a diameter of <40 deg. The current study investigated whether differences in jumping performance exist when athletes have loss of different visual function (VA or VF) but grouped within the same classification. Athletes were required to complete drop jumps under different simulated conditions of VI and without simulated VI (i.e., their habitual vision). Results from the study demonstrate that VI negatively impacts drop jump performance, but only when VF is constricted (B2-VF condition). Performance does not appear to be affected in conditions which reduce VA (B2-VA or B3-VA condition).

Peak jump height was 40% lower in B2-VF (95% CI: 0.24—0.32m) compared to Full vision condition (95% CI: 0.38—0.46m, figure 2, table 2). The reduction in peak jump height was caused through reduced vertical velocity at take-off and peak power generated (20% reduction for both variables) to propel the individual into the air (figure 2). In B2-VF vision condition, despite longer ground contact time (0.1sec, 24% increase) compared to Full, comparison of confidence intervals (Full 95% CI: 0.31—0.48sec, B2-VF 95% CI: 0.42—0.59sec) suggests that differences were not meaningful. Nevertheless, the combination of reduced peak jump height and slightly longer ground contact time resulted in the observed 34% reduction in RSI (Full 95% CI: 1.02—1.35, B2-VF 95% CI: 0.68—1.00).

Whilst there may not have been meaningful differences in ground contact time between B2-VF and Full vision conditions, the difference in performance (table 2) suggests that adaptations had occurred in B2-VF whilst in contact with the ground. With the occlusion of the peripheral VF likely impacting pre-activation of lower limb musculature prior to ground contact [7] and the ability to 'fine tune' landing behaviour,[12] it is likely that in B2-VF condition, a longer time within the initial period of ground contact was required to appropriately attenuate the landing impact forces before being able to subsequently generate vertical force. And since the time to generate vertical force was diminished (a longer time attenuating the impact forces and no meaningful increase in contact time), this negatively impacted subsequent jump performance.

In comparison to Full, blurring vision (B2-VA) only had a minimal impact on drop jump performance; milder blurring of vision (B3-VA) had a negligible impact. Despite observing a 16% reduction in peak jump height in B2-VA when compared to Full (11% reduction between Full and B3-VA), these differences were not meaningful (Full 95% CI: 0.38—0.46m, B2-VA 95% CI: 0.31—0.40m, B3-VA 95% CI: 0.33—0.42m); smaller differences are observed in other dependant variables (figure 2, table 2). These results suggest that mild/moderate blurring of vision has minimal impact on drop jump performance. It is recognised, that the current study did not blur vision beyond 1.60 logMAR or test performance in B1 vision condition. Within the wider sporting literature, the impact of degraded VA on performance appears dependent upon the specific requirements of the sport; which is why the Classification Code of the International Paralympic Committee (IPC) highlights the need for the development and implementation of robust classification systems that are evidence-based and sport-specific.[20,21] For example, during set shot shooting in basketball, Applegate[22] demonstrated that reducing VA to 1.10 logMAR (the poorest level of VA tested) had no impact on shooting performance. However, in rifle shooting, reductions in VA poorer than 0.5 logMAR were associated with reduced performance.[23] During golf putting, it was only when VA reduced to 2.00 logMAR a decrease in putting accuracy was observed,[24] and within cricket, batting performance degraded once VA reduced to ~1.00 logMAR,[25] but when bowling speed increased, performance decrements were evident at a lower level of blur (~0.50 logMAR,[26]).

Findings from the current study suggest an increased importance of the VF compared to VA in mediating drop jump performance (within the visual ranges tested). When dropping onto the lower level, the time-to-collision (also termed time-to-contact) with the ground is controlled through falling/dropping speed acquired from the peripheral VF (e.g.,[27,28]). In B2-VF condition, due to the occlusion of the peripheral VF, information relating to dropping speed to regulate time-to-contact with the ground will have been absent. However, in B2-VA and B3-VA conditions, it was still possible to acquire information from the peripheral VF. In these conditions, despite the peripheral VF being blurred, since visual motion uses low spatial frequencies and remains relatively effective despite losses in VA, degradation in VA would not have impacted the accurate acquisition of visual information from the peripheral VF to regulate time-to-contact.[29,30] One may therefore hypothesis that even under severe reductions in VA (i.e., B1 classification) athletes could still acquire visual information from the peripheral VF to regulate landing and produce jumping performance comparable to Full vision condition. This, however, is speculative and requires further investigation.

It is important to recognise that VI classification in B2 and B3 is based on impairment in either VA or VF and athletes may have a combination of loss in both VF and VA. Within the current study, testing both the individual and combined impact of VA and VF on drop jump performance was not feasible since additional jumps / conditions would have resulted in performance decrements through lower limb neuromuscular fatigue and not vision condition. The combined effect of VF and VA on drop jump performance is area of investigation recommended for the future. The impact of neuromuscular fatigue was also a determinant for not including a B3-VF or B1 conditions within this study.

Participants recruited to the current study can be defined as sub-elite, trained athletes and produced comparable jump heights to sub-elite sprinters [31] and trained American Collegiate Athletic Association (ACAA) division 1 volleyball players. [32] Despite the competitive standard of the participants recruited to the current study, they were athletes with normal vision. Whilst simulating VI in fully sighted athletes is one of three important approaches for sport classification research, [33] this approach does not account for any adaptations that VI athletes have undergone. For example, individuals with habitual VI demonstrate a lower visual contribution to regulating balance, with increased reliance on other sensory systems [34] and learn to capitalise on their remaining vision through training. [33]

In the current study, negotiating 'stepping stones' to reach the start position was included such that estimating drop height placed an increased reliance on the visual system. Whilst this methodological design increased the role vision played in mediating landing behaviour and subsequent jumping performance, the likely disruption from somatosensory and/or proprioceptive feedback may have overestimated our findings. Furthermore, whilst jump performance of the B2-VA class was not markedly affected, it should be noted that VAs in this category were at the ‘better’ end of the VA range at a mean of 1.62±0.02 logMAR. It needs to be established in further research whether VA at the more ‘severe’ end of B2-VA class (i.e., 2.50 logMAR) similarly impacts performance.

Only male athletes participated in this study. Unfortunately, the study was not able to recruit females who were at the required participatory level to be eligible for the study and we therefore recognise that our work (sadly) adds to the reported gender gap in sport and exercise medicine research. [35] The study therefore represents only a starting point in determining the impact of different aspects of VI on jump performance and potential classification in VI sport. Further research is needed to determine if the conclusions of the study also apply to female athletes.

The findings from this research have implications for the applied sports practitioner to consider. Despite the widespread evidence advocating the importance of utilising drop jumps within plyometric training for the development of lower limb explosive muscular power, when working with VI athletes who have severely constricted VF, this task may not be the most appropriate for inclusion in their training. Instead, other activities may better develop lower limb explosive muscular power, such as heavy resistance training. The same also applies to considering best practice for evaluating lower limb explosive power within VI athletes.

Summary

The current research demonstrates how jump performance is compromised in male VI athletes when measured through a drop jump. Decrements in performance, however, appear specific to those with severely constricted VF (B2-VF vision condition only). Those with reduced VA (B2-VA and B3-VA) appear to produce performance comparable to Full vision condition; However, simulated VI in B2-VA was closer to 1.50 logMAR as opposed to 2.60 logMAR within this class. The IPC advocate the need for the development and implementation of robust sport specific classification systems.[20,21] Findings from the current study suggest that high jump, long jump and triple jump events may need a greater emphasis on VF within their classification system and that grouping athletes in the same classification based on VA and VF may not be suitable. However, additional work is required to provide a unified consensus prior to considering changes in a classification system.

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Figure 1. Five key instances in the drop jump. The individual assumes the start position (A) and drops onto the lower level (B) and once the impact forces have been attenuated (C), propels upwards and leaves the floor (D) reaching peak jump height (E) before returning to land.

Figure 2. Mean value across drop jump height for each vision condition with 95% confidence interval (CI) upper and lower bounds plotted. Vertical velocity of the centre of mass at the instance of take-off (upper left panel), peak jump height (upper right panel), Reactive Strength Index (RSI, lower left panel) and peak Power (lower right panel).

Table 1. Summary statistics for each participant's visual acuity (VA) and visual field (VF) score for the three simulated vision impairment conditions.

Table 2. Averages (±SD) for Vision (collapsed drop height) and Drop Height (collapsed vision condition) for each dependant variable.

Table 1

Table 1. Summary statistics for each participant's visual acuity (VA) and visual field (VF) score for the three simulated vision impairment conditions.

	B3-VA VA (logMAR)	B2-VA VA (logMAR)	B2-VF VF (deg)
Participant 1	1.32	1.60	6
Participant 2	1.30	1.62	8
Participant 3	1.34	1.66	5
Participant 4	1.32	1.60	9
Participant 5	1.30	1.62	9
Participant 6	1.34	1.66	7
Participant 7	1.32	1.60	8
Participant 8	1.32	1.64	9
Participant 9	1.30	1.60	5
Participant 10	1.30	1.62	7
Range	1.30-1.34	1.60-1.66	5-9

Table 2

Table 2. Averages (±SD) for Vision (collapsed drop height) and Drop Height (collapsed vision condition) for each dependant variable.

	Vision condition				Drop Height (cm)			
	Full	B2-VA	B2-VF	B3-VA	30	40	50	60
Contact time (sec)								
	0.40	0.43	0.50	0.41	0.43	0.43	0.44	0.45
	(0.10)	(0.13)	(0.18)	(0.12)	(0.14)	(0.13)	(0.12)	(0.18)
Take off velocity ($m.s^{-1}$)	2.84	2.62	2.32	2.69	2.42	2.57	2.71	2.77
	(0.35)	(0.29)	(0.29)	(0.31)	(0.36)	(0.32)	(0.32)	(0.35)
Jump height (m)	0.42	0.35	0.28	0.38	0.31	0.34	0.38	0.40
	(0.10)	(0.08)	(0.07)	(0.08)	(0.09)	(0.08)	(0.09)	(0.10)
RSI								
	1.18	1.05	0.84	1.13	1.04	1.05	1.06	1.06
	(0.26)	(0.27)	(0.18)	(0.31)	(0.32)	(0.30)	(0.28)	(0.27)
Power (W)								
	2322	2143	1892	2201	1979	2102	2216	2261
	(485)	(429)	(375)	(451)	(443)	(440)	(465)	(457)

VA-visual acuity, VF-Visual Field.

Figure 1

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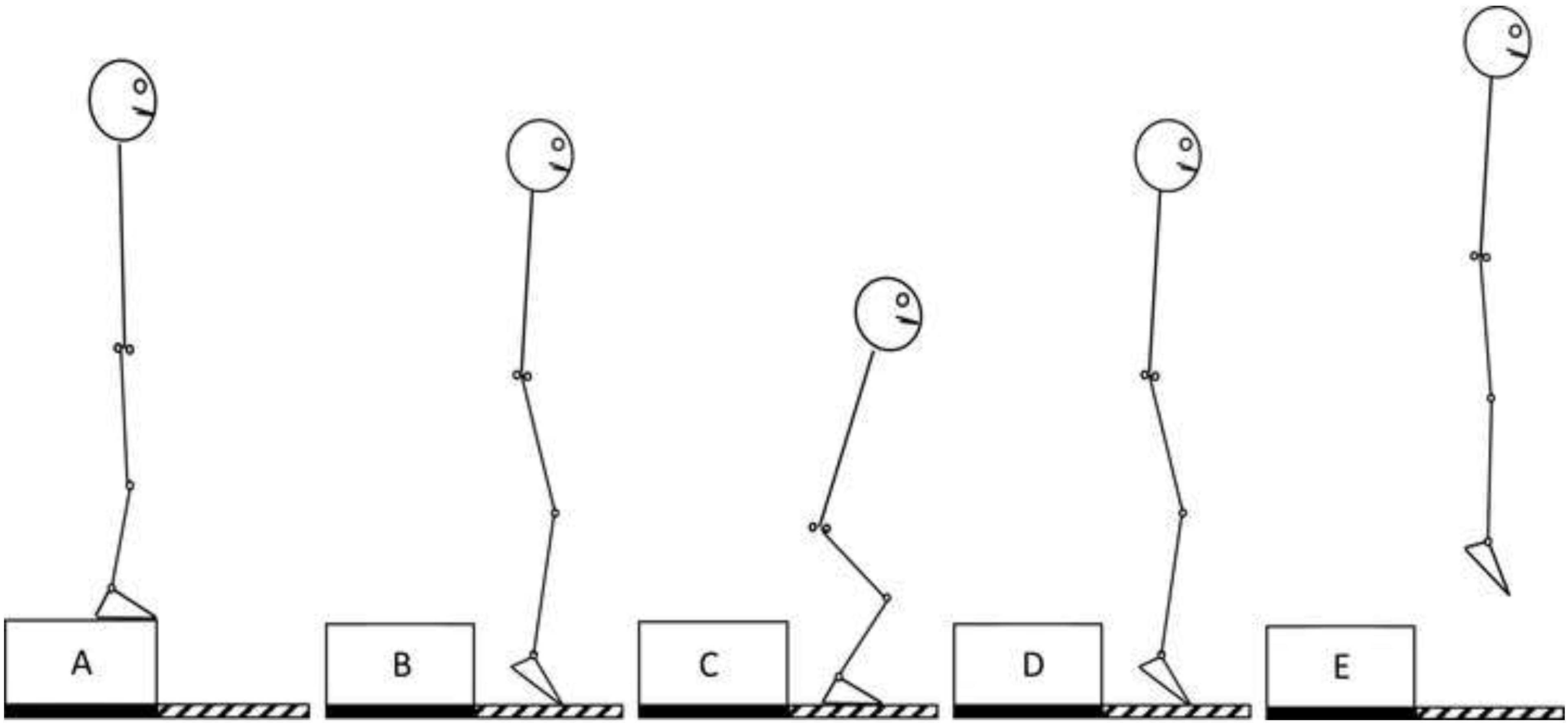

Figure 2

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