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The effects of blurred vision on the mechanics of landing during stepping down by the elderly

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Abstract

Visual impairment is an important risk factor for falls. However, relatively little is known about how visual impairment affects stair or step negotiation. The aim of the present study was to determine the effects of blurred vision on the mechanics of landing during stepping down by the elderly. Twelve elderly subjects (72.3 ± 4.7 year) stepped down from three levels (7.2 cm, 14.4 cm and 21.6 cm). Step execution time, ankle and knee joint angular displacements at the instance of ground contact, and vertical landing stiffness and the amount of bodyweight supported by the contralateral (support) limb during the initial contact period were recorded. Measurements were repeated with vision blurred by light scattering lenses. With blurred vision, step execution time increased ($P < 0.05$), knee flexion and ankle plantar-flexion increased ($P < 0.05$), vertical stiffness decreased ($P < 0.01$), and the amount of bodyweight being supported by the contralateral leg increased ($P < 0.05$). These findings suggest that under conditions of blurred vision, subjects were more cautious and attempted to 'feel' their way to the floor rather than 'drop' on to it. This may have been an adaptation to increase the kinaesthetic information from the lower limb to make up for the unreliable or incomplete visual information. Correcting common visual problems such as uncorrected refractive errors and cataract may be an important intervention strategy in improving how the elderly negotiate stairs.

Keywords: Stiffness; Elderly; Visual impairment; Falling; Stepping

1. Introduction

Visual impairment has been found to be associated with an increased risk of falling in the elderly [1–6]. For example, the study by Jack et al. [4] found that half of the elderly patients admitted to an acute geriatric clinic were reported to have impaired vision (best eye acuity worse than 6/18), with a high prevalence (76%) of visual impairment in patients admitted due to falls. Moreover, studies that report the incidence of falling indicate stair negotiation to be a particular problem for the elderly [7], with falls on stairs and steps being the leading cause of accidental death [8,9] and with stair descent being three times more hazardous than stair ascent [10–12]. However, relatively little is known about how visual impairment affects balance control and mobility on stairs and over steps.

The previous studies that have investigated the effects of vision impairment on descending steps or stairs indicate that a reduction in luminance has little effect on the ground contact forces in young or elderly subjects [13]. However, blurring vision causes the elderly to have difficulty in clearly defining the edge of the step and/or discriminating between the step's horizontal and vertical surfaces during stair descent [7,14] resulting in an increase in toe clearance [14]. This suggests that blurred vision, rather than a reduction in luminance, will effect how the elderly descend steps and stairs.

Impaired vision may make tripping while stepping down more likely because even small errors in locating the step could mean 'catching' the edge of the stairs or step with the foot or placing the foot in an unsafe position becomes more probable. However, it is also possible that elderly individuals with visual impairment fall when negotiating stairs and steps because they lack accurate visual information regarding when foot contact will be made and thus they stumble or slip because they land on a limb that is not fully ready

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to accept their bodyweight. In a recent study, Santello et al. [15] demonstrated that the occlusion of vision resulted in increased muscle pre-activation in the lower extremity when landing from a drop, and this resulted in a significantly higher vertical peak ground reaction force (GRF). The authors implied that subjects braced themselves by altering the kinetics of the landing limb because they were unsure of exactly when ground contact would occur. In the present study, we investigate whether blurring vision would have similar effects on the mechanics of landing when stepping down from various heights. It is known that the vast majority of visually impaired people are elderly, with much of the visual impairment potentially being reversible either by means of correcting refractive errors or removal of cataracts [16], thus it is important to understand how blurred vision can affect how the elderly descend stairs/steps.

2. Materials and methods

2.1. Subjects

Twelve healthy elderly subjects (seven male, five female) with a mean age (±S.D.) of 72.3 ± 4.7 years, and body mass and stature, respectively of 73.0±11.3 kg and 162.8±8.8 cm, volunteered to take part. An assessment was made to ensure that no subjects had a history of falls. A fall was defined as falling all the way to the floor or ground, falling and hitting an object like a chair or stair, or falling from one level to another, for example from bed to the ground [17]. Subjects were also screened using a self-report health questionnaire. Subjects suffering from any cardiac arrhythmias, vestibular disturbances, diabetes or severe arthritic conditions and subjects taking medications affecting balance were excluded, as were those with a history of amblyopia, strabismus, eye disease or ocular surgery. Binocular optimal visual acuity (VA) was assessed (see below) and individuals worse than 0.0 log MAR (Snellen equivalent 6/6) were also excluded. All subjects reported they engaged in light to moderate physical activities as defined by the 1992 National Fitness Survey [18] for example, walking, gardening, or social dancing for at least 30 min per day, five days a week. Apart from being physically active, this indicated that the subjects were all independently mobile. The tenets of the Declaration of Helsinki were followed and the study met with local bioethics committee approval. Written informed consent was obtained from all subjects.

All subjects had normal, healthy eyes by clinical examination, with mean visual acuity of −0.08 ± 0.03 log MAR (Snellen equivalent 6/5) and mean contrast sensitivity (CS) of 1.69 ± 0.09 log units, respectively. All stepping and visual assessments were performed using the subjects' optimal refractive correction, either with or without the addition of light scattering lenses. This was achieved by using full aperture trial lenses in a trial frame rather than using the subjects' own spectacles. More details regarding the visual function assessments can be found in previous reports [19,20]. With the addition of light scattering lenses CS was reduced to 0.95 ± 0.11 log units and visual acuity to 0.13 ± 0.08 log MAR (Snellen equivalent, 6/8).

2.2. Stepping down protocol and data collection

Data were collected during a single testing session for each subject. A 5-camera 3-D motion analysis system (Vicon 250, Oxford Metrics Ltd., Oxford, UK) was used to record (at 50 Hz) subjects stepping down from a single step, which was placed on top of a force platform, onto an adjacent force platform (AMTI OR6-7, Advanced Mechanical Technologies Inc., Boston, USA). The force platforms collected data at 100 Hz. The cameras were wall mounted at approximately 2.3 m above the floor and were positioned around the laboratory to view the performer from all directions (i.e. from approximately every 72°). Reflective markers (25 mm diameter) were attached either directly to the skin, onto clothing, or on elasticated bands over clothing, to the following body locations: second metatarsal heads, lateral malleoli, calcanei, lateral femoral condyles, anterior superior iliac spines, sacrum, lateral aspect of each shank and thigh, medial and lateral sides of wrists, lateral epicondyles, acromions and xiphoid processes, jugular notch, vertebrae T10 and C7, and the anterior-lateral and posterio-lateral aspects of the head. In general the markers located on the thorax and abdomen were attached onto clothing. As subjects had been asked to wear 'comfortable' clothing, clothing was taped and/or pinned to prevent wayward movements where necessary. Subjects stepped down to one of three levels, the height of which was equivalent to a kerb (low, 7.3 cm), a stair riser (medium, 14.6 cm) or stepping from a bus (high, 21.8 cm). These heights cover the range of step heights typically encountered in 'everyday' life [21]. The intra-subject comparison undertaken in the study meant normalising step height to subject height was not warranted.

The steps were constructed from 18 mm thick sections of medium density fibre-board (MDF), which were bonded together to form a solid block, the size of which covered the area of a single force platform (46.4 cm × 50.8 cm). No covering was used on the step but the force platforms were covered, like the surrounding floor, with foamed-backed vinyl floor covering (≈2 mm thick). Contrast and luminance of the step were measured as 58% and 400 (lx), respectively. Subjects wore their own 'comfortable flat' shoes. Each subject practiced stepping down from each of the three step heights, wearing trial frame spectacles set to provide optimal refractive correction and again when vision was blurred with the addition of the light scattering lenses.

Starting from a stationary standing position, with feet comfortably apart, subjects were asked to complete the step down in a single movement and to come to a stationary standing position on the force platform. For safety reasons, an observer stood approximately 1 m to the side of the force platform and subjects were informed that the observer was