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Subjective stability perception is related to postural anxiety in older subjects

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ABSTRACT

Background: Under static conditions, the objective and subjective measures of postural stability correlate well. However, age-related changes in postural control and task-related anxiety may modify the relationship between these subjective and objective measures. Ultimately, patients' symptoms represent subjective reports, thus understanding this relationship has clinical implications.
Aims: This study investigates the relationship between subjective-objective measures of postural stability in dynamic conditions and whether this relationship is influenced by age or task-related anxiety.
Methods: 50 healthy participants (aged 18–83 years) stood on a platform oscillating at variable amplitudes, with-without a fall-preventing harness to modulate task-related anxiety. Trunk sway path, hip velocity and foot lifts (objective measures) and subjective scores of instability and task-related anxiety were recorded.
Results: The subjective perception of stability accurately matched objective body sway, following a logarithmic function profile ($r^2 = 0.72$, $p < 0.001$). This function did not change significantly with age, harness or task presentation order. A strong relationship was observed between subjective measures of stability and task-related anxiety for all subjects ($r = 0.81$, $p < 0.001$). Task repetition reduced anxiety in the young, uncoupling anxiety changes from subjective instability, but not in the elderly who retained higher anxiety levels in line with subjective unsteadiness.
Discussion: Subjects accurately rate their own instability during dynamic postural challenges, irrespective of age and actual fall risk. However, anxiety may selectively modulate the perception of instability in older subjects. The perception of stability relies upon the integration of sensory afferents but also recruits emotional-cognitive processes, particularly in older individuals. The use of a safety harness has no influence on subjective or objective postural stability.

1. Introduction

Postural control involves three primary inputs from the visual, vestibular and proprioceptive sensors which provide information about body position, and are critical for postural control [1–4]. Postural control can be compromised in older subjects as a consequence of alteration in these inputs and their central integration [5]. Perception of postural insecurity induces anxiety which can further disrupt postural control [6]. However, the relationship between subjective (i.e. perceptual) and objective (i.e. body sway) stability and how it is modulated by factors such as age and anxiety during postural perturbations, remains unknown. This is of special interest in patients with persistent dizziness or imbalance in whom a distorted perception of postural stability may underlie the symptoms.

Previous studies have shown that, during quiet stance, there is a strong relationship between objective and subjective measures of postural stability in normal subjects and neurological patients [7–9]. However, no study has assessed this relationship in dynamic challenging situations as encountered in everyday life, where postural threats are externally imposed and unpredictable, a more real-life scenario.

Similarly, it is not known if the relationship between objective and subjective balance is affected by age or anxiety, factors which have been evidenced to influence postural control and therefore are potentially relevant to the development of fall anxiety in older people [10,6,11–14].

Accordingly, the aim of this study is to investigate the association

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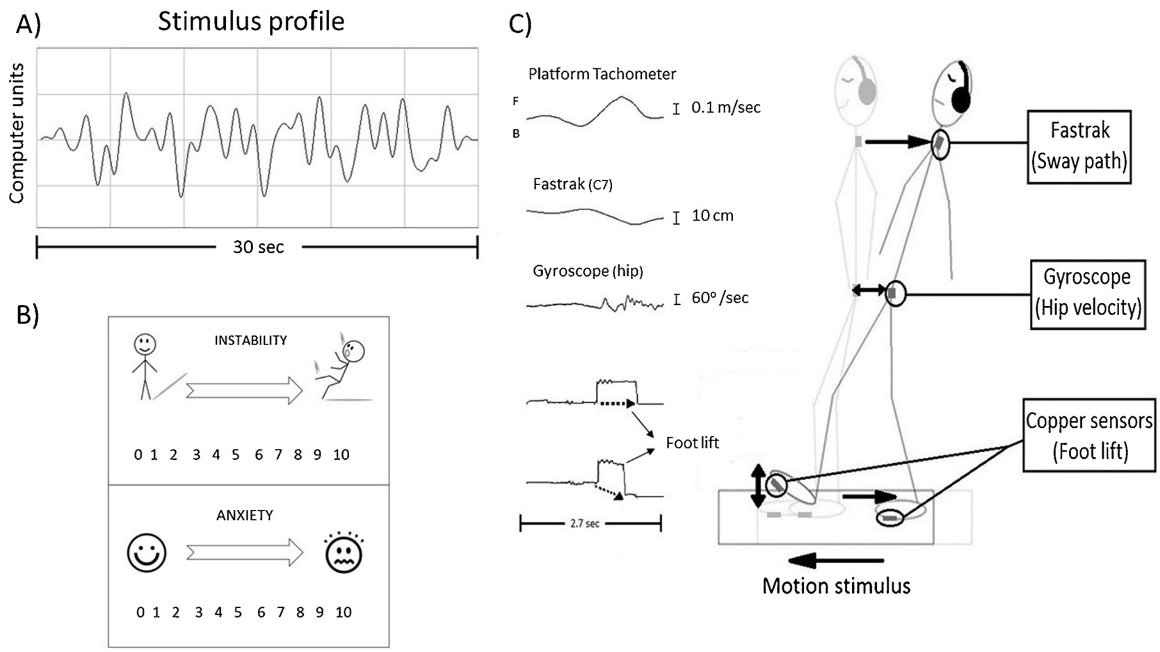

Fig. 1. A) Stimulus profile used to drive the platform, consisting of mixed sinusoidal waves at frequencies of 0.18, 0.37, 0.69 and 0.9 Hz over a 30 s period. This computer-generated stimulus was variably amplified to generate the velocity ranges shown in value 1. B) Subjective instability and anxiety scales used to assess the subjective measures after each trial. C) Schematic representation of the subject's body movement on the platform (right) and raw traces from the body motion sensors (left). Forwards ('F') platform displacements appear as upwards deviations on the velocity trace (tachometer) and backwards platform displacement ('B') as downward deviations. A forward platform displacement induces backwards body sway, as represented in the cartoon and recorded as a downwards deflection in the Fastrak (C7 sensor) and gyroscope traces (hip angular velocity). The bottom two traces are from the right and left foot contact detectors, respectively, showing in this case that the right foot trace went back to baseline (i.e. foot lifted but not displaced) whilst the left foot moved backwards by 7 cm as indicated by the height change in the trace, marked with the dotted downwards arrow. In the analysis, the number of foot lifts for each subject were counted, whether or not the foot was displaced.

between objective body sway and subjective (perceived) instability during a continuous translational platform movement. A related question is how perceived anxiety relates to both objective and subjective stability following a continuous postural perturbation. Lastly, we investigate the effects of age upon the association between objective and subjective stability, and perceived anxiety.

We make four key predictions: firstly, subjective instability during continuous unpredictable postural perturbations is tightly associated with objective body displacement. Secondly, we expect that these objective and subjective instability measures are closely linked to task-related anxiety. Thirdly, that anxiety can be modified using a safety harness, and finally, that the tight relationship between objective and subjective stability would be disrupted by increasing age. If the latter is true, age-related decline in vestibular and proprioceptive afferents could account for the change in the perception of stability with age.

2. Material and methods

This study was approved by the North East–York Research Ethics Committee.

2.1. Subjects

Fifty healthy individuals (28 females) age-range 18–83 years old (mean: 48.2 years) were recruited. Participants had no otological, neurological or psychiatric disorder and could stand unaided. For age-related comparisons, subjects were clustered by age into three groups: "Young" (18–34years; N = 18. Mean age = 27.8 ± 5.0), "Middle-age" (35-59years; N = 15. Mean age = 47.0 ± 8.1) and "Old" (60–83years; N = 17. Mean age = 70.9 ± 6.2).

2.2. Questionnaire assessment

Prior to the postural task, each participant completed three questionnaires: the Vertigo Symptom Scale (VSS-short form) [15], the Falls Efficacy Scale-International (FES-I) [16], and the Hospital Anxiety and Depression Scale (HADS) [17].

2.3. Proprioceptive thresholds

We assessed ankle and knee proprioceptive thresholds using a calibrated 64 Hz tuning fork (Aesculap, Germany) as described in Bergin et al. (1995) [18], whereby subjects report when the vibration at the medial malleolus and tibial tuberosity is no longer felt. At this point, marks on the tuning fork show the vibratory perceptual threshold in arbitrary units [18].

2.4. Vestibular thresholds

We determined vestibular perceptual thresholds using a procedure previously described [19,20]. Subjects sat on a vibration-free rotatory chair (Contravez Goerz, Pittsburgh, USA), in a light-proof room, whilst masking noise was amplified through headphones. The chair was rotated from a stationary position with an initial acceleration of $0.3°/s^2$, increasing by $0.3°/s^2$ every 3 s. Subjects were instructed to press a button (left or right) to indicate the onset of rotation perception and its direction. This procedure was repeated three times in each direction and the time taken to press the button (corresponding to the chair velocity reached at that point) was averaged to derive a single threshold for the subject [19].

2.5. Postural task

Participants stood on a computer-driven, velocity-controlled platform, powered by two linear motors [21]. All subjects wore a safety harness, i) attached to a rail placed above the platform, henceforth functional "harness" condition and ii) not attached to the rail, i.e. not functional "no-harness" condition. The order of these two conditions was randomised between subjects and participants were made fully aware whether the harness was functional or not.

The stimulus was created using a custom-made software ("Arbwave" D. Buckwell) and consisted of a combination of 4 harmonically unrelated sinewaves of different frequencies (0.18, 0.37, 0.69 and 0.9 Hz; Fig. 1A). The highest frequency is half the amplitude of the other 3 to avoid large brisk movements which could be potentially dangerous. The start and end of the stimulus (i.e. first and last second of the stimulus) are tapered to zero to avoid sudden onsets and stops. This stimulus-induced back and forth oscillations in a fixed sequence that could not be guessed by the subjects (pseudo-random), lasting a total of 30 s. Finally, the waveform was amplified using a linear potentiometer at 1, 1.5, 2 and 3 times the original waveform amplitude to generate a wider velocity range as detailed in Appendix 1 (peak sled velocity range was 0.01 to 0.2 m/s). There was also an "off" stimulus, in which the motors were switched off, and a "0 velocity" stimulus (linear motors "on" but without the computer input where subjects just perceived the slight humming but no overt translation) (Appendix 1). These 6 stimuli were pseudo-randomised, and each stimulus was delivered twice (12 stimuli in total per condition), with half of the subjects receiving first the harness condition, followed by no-harness, and half the subjects in reversed order. Subjects stood on the platform, with feet placed apart approximately 20 cm and eyes closed, facing the length of the track so most of the motion-induced sway would be in the sagittal "pitch" plane. Subjects were instructed to stand on the platform and remain stable. They were asked to refrain themselves from holding the platform bars but were instead encouraged to take corrective steps if needed.

2.6. Objective postural recordings

Three body sensors were used to record the subject's postural movements: i) a Fastrak electromagnetic sensor (Vermont, USA), placed at the C7 vertebral level to record linear displacement of the upper body in reference to the platform [21–24]; ii) a gyroscope placed over the right iliac crest recording hip-level angular velocity; and iii) electrical foot contact sensors, positioned on each foot's shoe sole to identify foot lifts and steps. All signals were recorded at 250 Hz.

2.7. Subjective postural and anxiety measures

Immediately after each 30 s trial, subjects were requested to verbally rate their degree of instability during the trial ("how unstable did you feel during the trial?") using a 0–10 ranked scale, where 0 corresponds to being "completely steady" and 10 "so unsteady that I would fall" (modified from Schieppati et al., 1999). Participants were then asked to rate their degree of anxiety across each trial on a scale from 0 "not at all anxious" to 10 "extremely anxious". Half points were allowed when subjects were undecided between two digits; e.g. if they said "between 2 and 3″ a value of 2.5 was allocated for that trial. Both scales were cartoon-aided (Fig. 1B).

2.8. Signal analysis

Objective instability was operationally defined as the degree of physical body movement as recorded by the sensors used, i.e. "sway path" (cumulative linear C7 displacement in the 30 s trial), "hip velocity" (Root Mean Square [RMS] of hip angular velocity), and "foot lifts" (number of times any foot was lifted during each trial) (Fig. 1C). Increases in these measurements are taken as evidence of postural instability [25]. For the analysis, both trials of the same stimulus and condition (6 stimuli performed twice) were averaged for each subject.

Statistical analysis was performed using SPSS version 24. Firstly, to explore the relationship between the objective measures of body sway and the subjective instability score, we applied Spearman correlations and a regression model with curve estimation to identify the best fit. Secondly, the same statistical analysis was used to explore the relationship between subjective instability and anxiety. Thirdly, to identify if the use of a safety harness had an effect upon the subject's objective and subjective measures, we used the Wilcoxon and two factors ANOVA tests to compare harness versus no-harness conditions and to evaluate the effect of stimulus amplitude and age groups within each harness condition. Finally, to characterise the possible differences in performance and in the objective-subjective relationship between the age groups, a one-way ANOVA test was used.

3. Results

3.1. Objective-subjective instability relationship

To avoid any influence of repetition of the task, only the data from the first condition to which subjects were exposed was used in the relationship analysis. The three objective measures of instability were correlated to explore their relationship to postural instability and a strong significant correlation was observed between all measures ($r = 0.94$ for sway path-hip velocity, $r = 0.86$ for sway path-foot lifts and $r = 0.85$ for hip velocity-foot lifts; $p < 0.001$ for all comparisons; Appendix 2). The different stimulus amplitudes induced significantly larger sway path during the larger stimuli (amplitude 3-4-5) but not during the smaller amplitude (Appendix 3). The Root Mean Square (RMS) of the C7 sway trace was also calculated in order to confirm that the sway path values were not being influenced by large changes in body sway amplitude or frequency. We correlated this measure with the rest of the objective measures (sway path, hip velocity and foot lifts) as shown on Appendix 4. Sway path showed a stronger correlation than sway RMS with the objective and subjective measures and, therefore, sway path was selected as the representative upper trunk displacement measure.

We correlated the three selected objective instability measures (sway path, hip velocity and foot lifts) with both subjective instability and anxiety. Although all these correlations were strong (all $p < 0.001$; Table 1), the strongest one was with C7 sway path and, therefore, C7 sway path was used for the statistical regression model with subjective instability. Regression-based curve fitting, for the whole group and for each age category, showed that logarithmic curves provided the best fit (Fig. 2A; $r^2 = 0.72, p < 0.001$). A logarithmic scale was used for the sway path variable to plot the relationship as linear and make it easier to compare (Fig. 2B).

3.2. Age effect

The three age groups were separated, and the regression was performed on the individual trial data points (N = 90–108) for each group independently. Regression curves between sway path and subjective instability between the three age groups were not significantly different when comparing the confidence intervals of the slope on each group

Table 1
Correlation between objective measures of body sway and subjective measures of instability and anxiety across all subjects. Only data from the first trial were used.

	Subjective Instability		Anxiety	
	Correlation coefficient (r)	Significance (p-value)	Correlation coefficient (r)	Significance (p-value)
Sway path	0.86	< 0.001	0.67	< 0.001
Hip velocity	0.82	< 0.001	0.62	< 0.001
Foot lift count	0.78	< 0.001	0.64	< 0.001

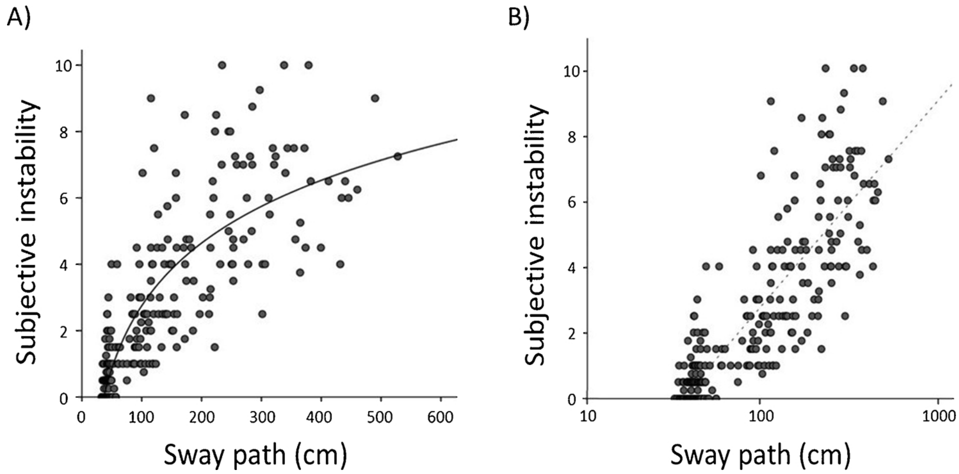

Fig. 2. A) Logarithmic (most parsimonious fit) regression for the objective measure of sway path (x-axis) and the subjective measure of instability (y-axis) for the first exposure to the experiment. B) The same regression with the sway path variable in log scale changes to linear ($r^2 = 0.72$; $p < 0.01$).

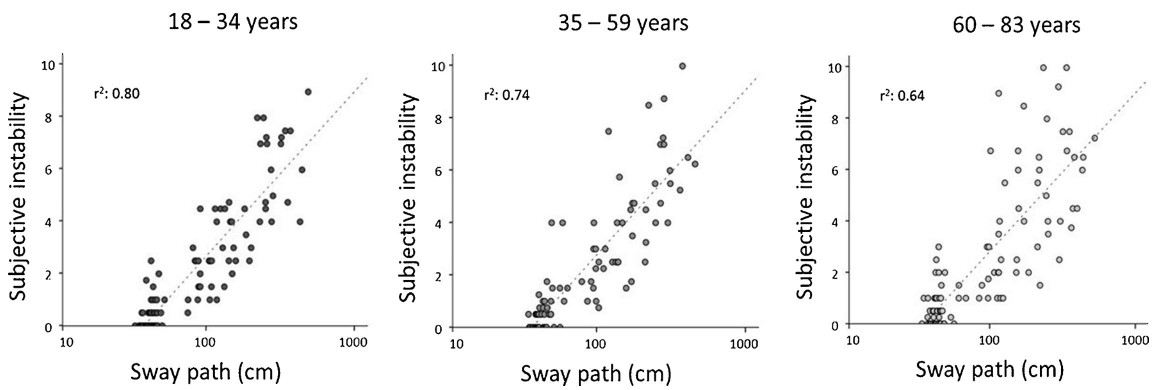

Fig. 3. Logarithmic regression between sway path (in log scale) and subjective instability score, for the three age groups. There was no significant difference in the slope of the three curves, but a higher variability was observed in the group Old compared to the group Young.

regression (Fig. 3). Objective-subjective regression curves were generated for each subject and then the individual slopes were averaged for each age group (Young, N = 18, mean = 2.80 ± 0.74; Middle-age, N = 15, mean = 2.70 ± 0.80, Old, N = 17,mean = 2.90 ± 1.24). Similarly, a one way ANOVA showed no differences for the mean slope values between the three age groups ($F = 0.17$,$p = 0.84$).

3.3. Harness effect

All objective and subjective measures in isolation, as well as the objective-subjective relationship slopes, were compared between the harness and no-harness conditions using the Wilcoxon test (Appendix 5). No differences were observed in any of the comparisons between both harness conditions. The individual objective-subjective slopes were averaged for each harness condition (no-harness, mean = 2.79 ± 0.96; harness, mean = 2.78 ± 0.95), and no differences were observed between the groups.

An ANOVA was performed for subjective instability, anxiety and sway path including harness as a factor and the three age groups as between-subjects factor. There was no interaction between the use of the harness and the age groups on any of the analysed variables ($p > 0.05$).

To further investigate the effect of harness use on anxiety levels, we performed a repeated measures ANOVA of anxiety with harness as the first factor and the different stimulus amplitudes as the second factor. The interaction between harness and stimulus amplitude showed a statistically significant effect on anxiety ($F = 4.30$,$p < 0.01$). This effect was only present in stimulus amplitude 5 ($p < 0.05$) in which the anxiety was reduced with the use of the harness as is shown on Appendix 6. In order to test the specific hypothesis that harness would have an effect only when combined with the presentation order (no-harness first or harness first), we included in the ANOVA harness use and its presentation order at each stimuli amplitude. We observed a significant interaction between harness and presentation order ($F = 8.52$,$p < 0.05$), indicating that the harness reduced anxiety for the high-intensity stimuli only when the task was repeated for the second time. The opposite polarity of this difference (Δ anxiety) confirms that the interaction between harness conditions and stimuli was largely due to the order of presentation rather than the actual use of the harness (Appendix 7).

3.4. Order effect

We explored the presence of an order effect given that each trial was performed once with harness and once without, in a different order. Comparison (repeated measures ANOVA) with the first and second runs as the main factor, revealed a significant reduction in anxiety scores, sway path and hip velocity, suggesting an order effect. Further analysis including the age groups showed that anxiety decreased only in group Young ($p < 0.01$) and that the objective measures of sway (sway path and hip velocity), decreased in group Old ($p < 0.001$ for sway path and $p < 0.01$ for hip velocity). The changes in anxiety scores between first and second runs for the Young group and in sway path for the Old group were significantly different from 0 and are shown on Appendix 8 (single value t-test; $p < 0.01$).

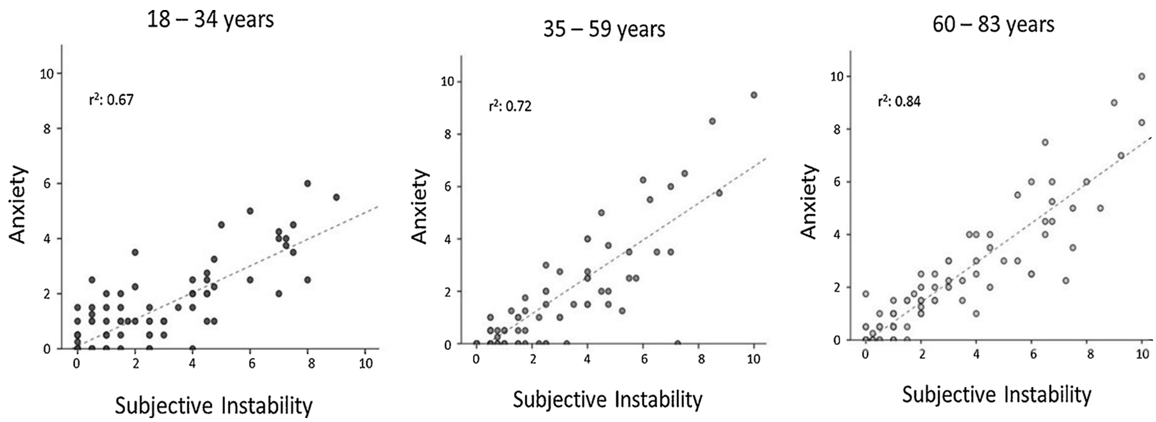

Fig. 4. Linear regression between subjective instability and task-related anxiety for each age group. Only data from the first trial were used. The curve slope was significantly steeper in the group Old (60–83 years) than in the Young (18–34 years) ($F = 4.38$, $p < 0.05$; ANOVA with Scheffe test).

3.5. Task-related anxiety

In order to firmly identify if both subjective variables were related (subjective instability vs. anxiety scores), we took a threefold approach. Firstly, we correlated all individual data points at all stimulus amplitudes. A significant positive correlation between subjective perception of instability and task-related anxiety was found ($r = 0.81, p < 0.001$). Second, we created a single point value per variable and subject, that is, averaging anxiety and subjective instability data from all stimuli. These single representations of anxiety and subjective instability were also strongly correlated ($N = 50, r = 0.83, p < 0.001$; Appendix 9). Finally, individual regressions were calculated for each subject, displayed in Appendix 10, showing that all subjects' trend is coherent with the whole sample results

To identify if the relationship between subjective instability and anxiety was similar across ages, we compared the mean slope values of the regression curves from each age group. We observed that subjective instability scores were related to higher anxiety levels in the group Old compared to the group Young (steeper curve, Fig. 4). To corroborate this finding, a one-way ANOVA with post-Hoc analysis was performed which showed a significant difference in curve slopes ($F = 4.38, p < 0.05$ in Scheffe test) and mean r^2 values ($F = 4.73, p < 0.05$; Appendix 11) between the Young and Old groups.

Having observed above ("order effect") a reduction in anxiety in Young group during the second experimental run, we wanted to establish if changes in subjective instability were related to changes in anxiety. Thus, we calculated the change in subjective instability (Δ subjective instability) and anxiety (Δ anxiety) between both experimental runs. In group Young, there was no significant correlation between Δ anxiety and Δ subjective instability ($r = 0.08, p = 0.39$), whilst in both Middle-Age and Old groups a positive significant correlation was present ($r = 0.46$, and $r = 0.59$, respectively, $p < 0.001$) (Fig. 5). Thus, changes in subjective instability are correlated with changes in anxiety in the Middle-age and Old groups but not in the Young.

3.6. Proprioceptive and vestibular thresholds

As expected, proprioceptive vibratory thresholds had a strong negative correlation with age, for both ankles and knees ($r = -0.67, p < 0.001$ and $r = -0.47, p < 0.001$, respectively). However, no correlation was observed between proprioceptive thresholds and any of the objective or subjective postural measures.

The mean vestibular perceptual threshold was 7.08 deg/s for the whole group, as in previous studies [19,20], but no correlation with age or any of the objective or subjective measures used was observed.

3.7. Questionnaires

Questionnaires scores (VSS, FES-I, HADS; Appendix 12) were positively correlated with age ($p < 0.001$) but mostly not with objective/subjective measures of instability/anxiety. The FES-I score was the only questionnaire that showed a (weak) positive correlation with anxiety scores reported during the tasks ($r = 0.15, p < 0.01$). The age group analysis showed a significant positive correlation between the anxiety scale of the HADS and the average task-related anxiety score in the group Old ($r = 0.55, p < 0.001$) but not in the other two groups, i.e. in old age, higher baseline anxiety scores correlated with higher anxiety levels in the postural task.

4. Discussion

4.1. Objective-subjective sway relationship

We show that subjective and objective measures of instability during a dynamic postural task are strongly correlated and, further, that postural instability is associated with task-related anxiety especially in older persons.

All objective measures used were highly correlated with each other. The fact that these measures are strongly inter-related – including foot lifts, which is a representation of the reflex protective response to a balance loss - confirms, as expected, that the body measures used in this study represent objective physical instability.

Healthy individuals are able to formulate an accurate perceptual assessment of their postural performance, confirming earlier observations in studies using a similar online measurement paradigm, albeit during quiet stance [7–9]. The robust relationship between objective and subjective instability, pervasive across all conditions in this and previous studies, is indicative of its strong biological significance.

4.2. Age effect and anxiety

Increased postural sway, and therefore increased perceived instability, was associated with greater postural anxiety, particularly under challenging conditions. Importantly, this relationship with anxiety is strongest in older subjects. Increased anxiety may thus develop upon perceiving increased instability but, alternatively, it could arise on detecting a more challenging task.

Why should greater perception of instability be correlated with greater anxiety in older people compared to young subjects? One possibility is that older subjects correctly identify that their sensory inputs have an age-related detriment which could lead to a deterioration of their balance function, in turn generating postural anxiety. This agrees with the negative correlation between proprioceptive perception and

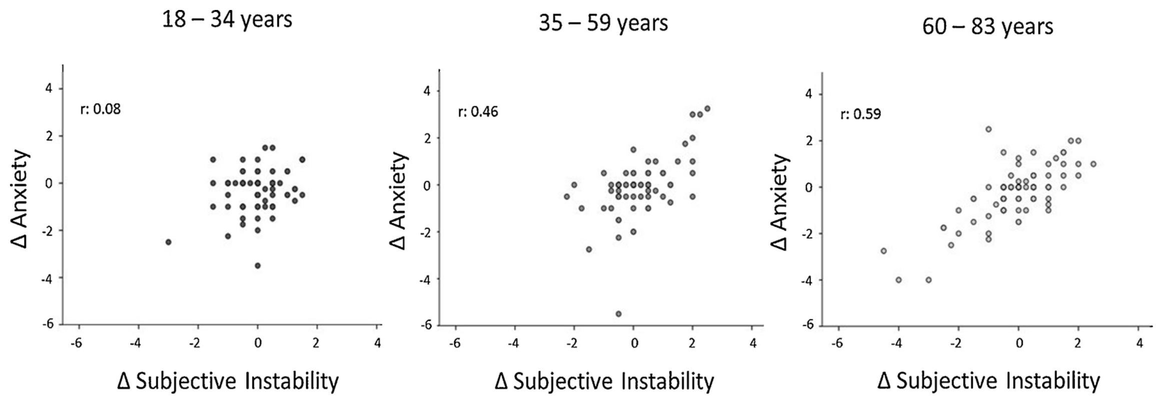

Fig. 5. Correlation between changes (Δ) in the subjective measures of instability and task-related anxiety between the first and second time the task was performed, for each age group. Correlation coefficients are shown indicating a stronger relationship between the Δ subjective instability and the Δ task-related anxiety in the two older groups ($p < 0.001$ for both groups).

age that we, and others [18,26,27], have found.

A further non-mutually exclusive possibility is that older subjects could harbour greater anxiety in relation to posture, irrespective of impaired balance mechanisms, through anticipating the implications of falling, with task-related anxiety possibly developing with appreciation of a significant postural threat [12,28,29]. Such a mechanism could contribute to the generation of "fear of falling" in older subjects, which increases when balance confidence diminishes [30–33]. In support of this, we observed (i) a significant correlation between fear of falling questionnaire data and task-related anxiety and, (ii) a reduction in postural sway when faced with the postural task for a second time (order effect) that was not accompanied by a reduction in subjective measures of anxiety or instability. One important observation, therefore, is that in older subjects, balance perception and fall-related anxiety may dissociate from objective postural instability measures. In older people, the observed postural anxiety may imply a subclinical fear of falling, which, is latent and arises when facing a challenging postural task. Accordingly, for a complete assessment of an older person's balance capabilities, in particular, fall-risk and fear of falling, tougher dynamic challenges may be required.

In stark contrast to the older group, younger individuals reduced anxiety on repeating the experimental procedure (order effect) but this had no effect on objective measures of postural sway or subjective instability. When facing an upcoming postural threat, young individuals still experience a degree of task anxiety but, once the challenge has been experienced and managed successfully, the experiential response to the task quickly adapts. Hence, low balance confidence levels in older people partly represent a cognitive adaptive failure to simple, repeated postural tasks.

4.3. Anxiety and postural control

Along similar lines, Young and Williams have recently proposed a model to understand the influence of "fear of falling" on postural balance. They postulated that fear of falling could cause a difficulty in drifting the attentional focus from non-relevant postural stimuli to those needed to maintain balance [6]. The lack of reduction in anxiety in our group Old the second time the task was performed, suggests that older subjects are less able to shift attention away from anxiety and are thus less able to focus on more relevant objective cues of stability. In parallel, increased anxiety, perhaps secondary to heightened postural threats, may increase sensory gain (hypersensitivity to sensory stimuli) in order to maintain self-perception of instability under threatening conditions [34]. Such mechanisms may perpetuate higher instability scores despite the reduction in objective postural instability on task repetition observed in older subjects.

Notably, the questionnaires commonly used for clinically assessing subjective balance symptoms did not show a relationship with the objective measures of postural stability in this study, suggesting that during the experiment individuals were relying upon an online, task-specific assessment for their perception of stability. However, general anxiety levels measured with the HADS correlated in older subjects with overall measures of task-related postural anxiety. Thus, treatment of general anxiety could have specific task-related benefits for older patients.

4.4. Vestibular and proprioceptive thresholds

Perhaps unexpectedly, we found no correlation between vestibular perceptual thresholds and objective measures of sway, suggesting that the balance mechanisms required for this task are less dependent on vestibular information. However, the platform oscillations delivered supra-threshold vestibular activation which would not necessarily correlate with vestibular thresholds. Indeed, significant disease-mediated dissociations of threshold and supra-threshold vestibular functions have been reported [35]. Additionally, neither vestibular nor proprioceptive perceptual thresholds showed a relationship with the subjective measures of instability or anxiety. We believe this finding means that postural perception is derived from a complex central integration of multiple sensory channels with cognitive factors and not just a linear summation of peripheral afferent information, as suggested earlier [7]. The finding that anxiety impacts on postural perception supports this view.

4.5. Harness effect

Although the use of harness did not have a direct/main effect on any variable, significant statistical interactions show that the harness reduced the anxiety experienced during the most challenging task particularly when the task was repeated. This makes common sense in that, having experienced an intense postural stimulus that might actually induce a fall, wearing a harness the second time proved reassuring and anxiety-reducing for the subjects. The harness is not expected to provide reassurance when there is no perceived fall risk. For this reason, it is not possible to confidently conclude that the use of the harness has an effect on anxiety. However, this and previous findings [36,37], suggest that actual postural sway is not influenced by harness use, carrying a practical implication for researchers in this field.

To conclude, we demonstrate that healthy subjects can accurately rate their own instability in dynamic conditions. This process requires not only the integration of sensory afferents but also recruits emotional (i.e. anxiety) and cognitive processes, that when taken together provide an overall sense of balance/imbalance. Our results highlight the importance of evaluating both objective and subjective measures of postural behaviour to monitor balance function in response to therapy, or as a clinical marker of balance function. In older participants, higher subjective instability and anxiety scores are maintained, despite the objective reduction in postural sway when repeating a postural task. These findings suggest that task (fall)-related anxiety could influence the perception of stability in the older population and should be targeted by therapy to improve confidence.

Conflict of interest

The authors of the present study declare they do not have any personal, professional or financial relationship that could imply a conflict of interest.

The present study has not been published before and it will not be submitted elsewhere while under consideration at Gait and Posture.

This research was approved by the North East–York Research Ethics Committee.

All authors of the present study have reviewed and approved the contents of the manuscript and validate the accuracy of the data.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.gaitpost.2018.12.043.

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