Cervical musculoskeletal, physical and psychological factors associated with ongoing dizziness in patients with whiplash associated disorder, 12 months after undertaking a neck specific or general exercise intervention

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Abstract

Background: Exercise in the management of persistent whiplash often doesn’t specifically address dizziness. This study aimed to determine cervical musculoskeletal and sensorimotor measures, quality of life and psychological factors associated with the presence of dizziness in individuals with persistent whiplash 12 months post exercise intervention commencement.

Methods: A retrospective cross sectional review of questionnaires on dizziness, physical and psychological disability, quality of life and physical measures prospectively collected from 172 individuals during a randomised controlled trial. Associations between dizziness at 12 months post intervention and possible predictors was analysed with simple and multiple logistic regression models.

Results: Sixty-three % reported dizziness with a mean University of California Los Angeles dizziness score of 9 (SD 5) and dizziness intensity during activity of 26 mm (SD 24). They had poorer performance on sharpened Rhomberg, Neck muscle endurance (NME), and range of motion, elevated scores on pain, Neck disability index (NDI) and psychological and quality of life measures compared to those without dizziness. Less improvement in NDI and NME flexion from baseline to 12 months post exercise commencement, along with some baseline covariates were related to persistent dizziness and explained 50% of the variance.

Conclusion: Dizziness following exercise at 12 months post follow-up was associated with lack of improvement in NDI and NME flexion suggesting a cervicogenic role. Alternatively, the presence of dizziness may inhibit exercise response. Additional causes or contributing factors of dizziness should be investigated in those with persistent whiplash to improve quality of life.
Background
It is estimated that up to 50% of persons sustaining neck trauma as a result of a motor vehicle collision will go on to have persistent problems [1] with multifactorial causes including biological, psychological and social factors [2, 3]. These patients present challenges to all professionals involved and present with a variety of symptoms. Understanding the relationships between these signs and symptoms is important to direct rehabilitation.

After pain, dizziness and unsteadiness is a frequent complaint, with up to 70% of those with persistent whiplash associated disorder (WAD) reporting these complaints [4]. These symptoms are thought to reflect abnormal cervical afferent to the sensorimotor control system in most patients and have been associated with objective deficits in head and eye movement control and postural stability relevant to a cervical cause [4–6]. A variety of causes of abnormal cervical afferent input following a whiplash injury have been highlighted in the literature including functional impairment of muscles, such as altered neuromotor control or increased fatigability [7]. In addition, the effects of pain at many levels of the nervous system can change muscle spindle sensitivity and alter the cortical representation and modulation of cervical afferent input [8]. Psychosocial stresses may also influence muscle spindle activity via activation of the sympathetic nervous system [9].

To date there is modest evidence for the effect of exercise in the management of WAD on pain and disability [10]. These treatments address some of the causes of altered cervical afferent input but do not specifically address factors associated with sensorimotor control such as dizziness, proprioception and balance. Previous studies have determined the effect of a specific neck, a combined specific neck and behavioural approach or a general exercise program on pain and disability [11] in persistent WAD and then specifically considered the effects of this program on symptoms of dizziness and deficits in sensorimotor control in those reporting dizziness and postural instability [12]. The later study found that although between and within group comparisons suggested that those performing the neck specific exercise had significant advantages in improving measures of dizziness and proprioception compared with the general physical exercise group, many still complained of dizziness and balance impairment at the 12-month follow-up [12].

To assist direction for management of dizziness in persistent WAD it will be important to understand factors associated with ongoing complaints of dizziness. Thus the aim of this study was to first compare cervical related physical and psychological factors in individuals with and without dizziness, 12 months after a neck specific or general exercise intervention and secondly to determine the combination of these factors to best predict those reporting ongoing dizziness. It was hypothesised that a combination of physical and psychological factors would predict those reporting ongoing dizziness.

Methods
This was a retrospective review of prospectively gathered data collected during a randomized controlled trial (RCT) (n=216, mean age of 40 (SD 11), 65% women). A detailed description of the RCT study design and the 12-week intervention can be found in [11, 12]. The interventions included A) Physiotherapist-guided neck specific exercise B) Physiotherapist-guided neck specific exercise, with a behavioural approach and C) Prescription of general Physical Activity.

Briefly, patients with a WAD diagnosis, at least 6 months but no more than 3 years after a motor vehicle collision, who fulfilled the eligibility criteria attended a physical examination to ensure eligibility. To be included in the original study participants had to be a WAD II or III [13] and have continuing pain (>20 mm on 100 mm Visual Analogue Scale (VAS) [14] and/or >20% on Neck Disability Index (NDI), 0–100%) [15]. Subjects were excluded if they had known or suspected serious physical pathology, earlier neck trauma, surgery or neck pain with persistent injury, signs of traumatic vestibular or brain injury at the time of WAD, generalized or more dominant pain elsewhere in the body, diseases or other injuries that might prevent full participation in the study, diagnosed severe psychiatric disorder or known drug abuse.

All measurements were conducted at baseline and 12 months post commencement of the intervention. Questionnaires covered aspects relating to dizziness and pain intensity and disability, psychological (catastrophising, kinesiophobia, self-efficacy, depression and anxiety) and health related quality of life measures. Clinical neck related measurements included cervical joint position sense, cervical range of motion (ROM) and neck flexor and extensor muscle endurance measures (NME). Measures of static (eyes closed rhomberg) and dynamic (figure of eight walk) balance were also considered. Information pertaining to all measurements, references regarding...
their psychometric properties and their abbreviations are included in Table 1. These were performed in a standardised way by well-trained investigators. Demographic data was also obtained.

**Data management and statistical analysis**

For the purposes of this study only data from participants who had completed all relevant measures at both baseline and at the 12-month follow-up as well as answered a yes/no question on dizziness and questions regarding dizziness and unsteadiness intensity at the 12-month mark were included. Data from eligible participants for this study was then pooled into two groups, no dizziness and dizziness, according to whether they complained of dizziness and unsteadiness at the 12-month follow-up or not, regardless of the intervention group. To be included in the dizziness at 12-months group, participants had to report dizziness, complete the University of California Los Angeles Dizziness (UCLA) questionnaire, and also rate more than 10 mm on either of the dizziness intensity or unsteadiness VAS (Fig. 1).

Between group differences for age at baseline, and dizziness intensity and unsteadiness, pain and disability, psychological and quality of life measures and physical measures at baseline, 12 months, and change between baseline and 12 months, were analysed with independent sample t-tests. All measures were presented as mean and standard deviation (SD) in Table 2. Cohen’s $d$ was calculated as an effect size measure in measures where the
A p-value <.05 was seen in the between group difference in change at 12 months.

Simple and multiple logistic regression models were used to analyse the association between the binary dependent variable of dizziness at 12 months and possible predictors, measured as change between baseline and 12-months follow-up. Both crude and adjusted odds ratios (OR) with 95% confidence intervals (CI) and Nagelkerke pseudo $R^2$ were explored. Baseline measures, gender, age, WAD-level, intervention (neck specific exercise including behavioural OR physical activity), dizziness, and each predictor were entered as covariates in the adjusted models. Predictors with a p-value <.20 in the simple logistic regression models were entered in the multiple model, using backward stepwise procedure. There was no multicollinearity among the predictors, the variance inflation factor varied between 1.1 and 3.1, which can be interpreted as low to moderate correlation. Level of significance was set at $p < .05$. The IBM SPSS statistical program 25.0 was used for all calculations.

**Results**

In total data from 172 of the original 216 participants were eligible for inclusion in this study. The mean age was 41 years (SD 11), and included 110 women, 97 were classified as WAD grade 2. While 125 participants complained of dizziness and 47 did not at baseline, at the 12-month assessment, 109 participants reported dizziness and 63 did not. (Fig. 1).

Table 2 depicts all data comparing participants with and without dizziness at the 12-month follow-up. The group with dizziness had higher levels of: neck pain (VAS), disability-NDI, pain disability index (PDI), pain catastrophising scale (PCS), hospital anxiety and depression scales (HAD-A, HAD-D), tampa scale of kinesiophobia (TSK), poorer self efficacy scale (SES) and EuroQuol quality of life (EQ-VAS), poorer neck muscle endurance (NME) and static balance and less total ROM.

According to HAD-A or HAD-D scores $> 10$, six (10%) participants showed probable anxiety and two (3%) probable depression in the non-dizzy group, while 26 (24%) participants showed probable anxiety and 18 (17%) probable depression in the dizzy group.

Table 3 depicts the results of the simple crude and adjusted logistic regression models on dizziness at the 12-month follow-up. Measures of change at 12 months in, VAS neck pain right now, NDI, PDI, NME flexors, and EQ-VAS showed significant association with dizziness at 12 months, based on the adjusted models.

Table 4 depicts the results of the final multivariable logistic regression model. Measures of change at 12 months in, NDI (OR .95, 95% CI .91–.98), and NME
| Type of measures | Variables | Baseline | 12 months | Change at 12 months |
|------------------|-----------|----------|-----------|---------------------|
|                  |           | No dizziness | Dizziness | Between group difference | No dizziness | Dizziness | Between group difference | p-value | Effect size |
|                  |           | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value | n | Mean (SD) | n | Mean (SD) | p-value | Effect size |
| Dizziness/       | VAS dizziness at rest (0–100 mm) | 2.4 (5.5) | 17.9 (22.5) | <.001 | 11.6 (16.9) | 108 | 64 (21.9) | .072 |
| unsteadiness     | VAS dizziness during activity (0–100 mm) | 10.0 (18.5) | 294 (27.3) | <.001 | 26.4 (24.4) | 107 | 2.4 (27.2) | |
|                  | VAS disturbed balance (0–100 mm) | 7.1 (13.3) | 236 (25.1) | <.001 | 24.7 (26.3) | 106 | −1.6 (25.3) | |
| Sensorimotor     | Sharpened Romberg (seconds) | 16.3 (10.2) | 123 (9.6) | .010 | 198 (100) | 59 | 3.8 (8.9) | .005 |
| physical         | Figure of eight (no. of steps) | 2.8 (4.0) | 39 (4.9) | .147 | 1.1 (1.9) | 57 | 1.7 (3.3) | .005 |
|                  | HRA mean left + right (mm) | 5.7 (4.1) | 7.5 (6.5) | .023 | 4.4 (4.0) | 57 | 1.2 (5.3) | .005 |
| Pain and         | VAS neck pain, now (0–100 mm) | 33.8 (24.3) | 45.8 (24.4) | .002 | 176 (23.6) | 62 | 16.6 (27.2) | .005 |
| disability       | Neck Disability Index (0–100%) | 25.6 (10.8) | 36.1 (13.0) | <.001 | 175 (13.7) | 61 | 8.9 (13.1) | .005 |
|                  | Pain Disability Index (0–70) | 14.3 (10.8) | 23.6 (13.9) | <.001 | 8.7 (8.8) | 62 | 5.8 (11.8) | .005 |
| Psychological     | Pain Catastrophizing Scale (0–52) | 16.0 (9.2) | 185 (11.2) | .147 | 106 (9.4) | 60 | 4.7 (8.1) | .005 |
|                  | HAD Anxiety (0–21) | 5.5 (3.5) | 7.0 (4.4) | .023 | 4.4 (3.4) | 60 | 1.1 (3.2) | .005 |
|                  | HAD Depression (0–21) | 2.9 (3.1) | 2.9 (4.4) | <.001 | 2.6 (2.9) | 59 | 3.3 (3.3) | .005 |
|                  | Self-Efficacy Scale (0–200) | 166.5 (31.4) | 143.0 (34.5) | <.001 | 172.4 (30.3) | 58 | 7.5 (30.9) | .005 |
|                  | Tampa Scale of Kinesiophobia (11–44) | 20.3 (5.2) | 22.8 (6.1) | .007 | 174 (5.2) | 59 | 2.6 (46) | .005 |
Table 2 (continued)

| Type of measures | Variables | Baseline | 12 months | Change at 12 months |
|------------------|-----------|----------|-----------|-------------------|
|                  |           | No dizziness | Dizziness | Between group difference | No dizziness | Dizziness | Between group difference |
|                  |           | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value | n Mean (SD) | n Mean (SD) | p-value | Effect size |
| Musculoskeletal physical | Age | 39.2 (10.9) | 42.5 (11.5) | .072 | 57.0 (50.6) | 34.9 (36.4) | .005 | 56 | 17.2 (41.7) | 103 | .7 (36.2) | .010 | .433 |
| | NME, flexion (seconds) | 43.0 (43.3) | 33.3 (48.0) | .190 | 57.0 (50.6) | 34.9 (36.4) | .005 | 56 | 17.2 (41.7) | 103 | .7 (36.2) | .010 | .433 |
| | NME, extension (seconds) | 129.4 (143.0) | 78.7 (110.7) | .018 | 195.7 (198.3) | 119.9 (235.7) | .045 | 54 | 84.7 (186.0) | 100 | 39.3 (202.8) | .174 |
| | ROM, flexion (degrees) | 49.0 (15.4) | 41.7 (14.3) | .002 | 528 (143) | 46.7 (13.6) | .007 | 59 | 3.4 (13.7) | 106 | 4.9 (12.3) | .478 |
| | ROM, extension (degrees) | 57.1 (15.5) | 50.4 (17.0) | .011 | 588 (151) | 50.8 (18.3) | .003 | 59 | 2.1 (12.0) | 106 | 4 (13.1) | .420 |
| | ROM, flexion + extension (degrees) | 106.0 (23.0) | 92.1 (26.2) | .001 | 1116 (239) | 97.4 (28.2) | .001 | 59 | 5.5 (18.1) | 106 | 5.3 (20.6) | .953 |
| | ROM, lateral flexion right + left (degrees) | 69.8 (15.4) | 63.5 (18.1) | .020 | 723 (16.2) | 64.4 (18.5) | .007 | 59 | 2.3 (7.2) | 106 | 1 (10.0) | .346 |
| | ROM, rotation right + left (degrees) | 114.6 (22.3) | 1084 (28.9) | .115 | 1249 (21.8) | 1112 (27.5) | .001 | 59 | 10.7 (16.6) | 106 | 3.1 (22.5) | .014 | .403 |
| Quality of life | EQ-SD Index (−594−1000) | .698 (180) | .581 (273) | .001 | .767 (211) | .611 (285) | <.001 | 60 | .067 (22.6) | 105 | 10.7 (267) | .335 |
| | EQ-VAS (0–100 mm) | 70.3 (14.6) | 58.9 (18.4) | <.001 | 772 (16.7) | 62.9 (21.4) | <.001 | 60 | 7.2 (16.8) | 106 | 3.9 (23.8) | .310 |

a Dizziness at 12 months follow-up is based on the yes/no question on dizziness and/or VAS > 10 mm in dizziness intensity/unsteadiness

VAS visual analogue scale; HRA head relocation accuracy; NME Neck muscle endurance; ROM range of motion; HAD-A HAD-D hospital anxiety and depression scales, EQ-SD EQ-VAS- EuroQuol quality of life index
Table 3  Simple crude and adjusted logistic regression models on dizziness at 12 months for relevant measures

| Type of measures | Measures of change at 12 months | n   | Crude B | Odds Ratio | 95% CI for Odds Ratio | p-value | Pseudo R² | Adjusted* B | Odds Ratio | 95% CI for Odds Ratio | p-value | Pseudo R² |
|------------------|--------------------------------|-----|---------|------------|-----------------------|---------|----------|------------|------------|-----------------------|---------|----------|
| **Pain and disability** | VAS neck pain, now (0–100 mm) | 170 | −0.014 | 0.986 | 0.973–0.999 | 0.033 | 0.037 | −0.029 | 0.971 | 0.953–0.989 | 0.002 | 0.426 |
|                  | Neck Disability Index (0–100%) | 168 | −0.039 | 0.962 | 0.938–0.986 | 0.002 | 0.080 | −0.061 | 0.941 | 0.909–0.974 | 0.001 | 0.467 |
|                  | Pain Disability Index (0–70) | 170 | −0.027 | 0.974 | 0.948–0.999 | 0.044 | 0.034 | −0.081 | 0.922 | 0.881–0.965 | 0.001 | 0.474 |
| **Psychological** | Pain Catastrophizing Scale (0–52) | 166 | −0.033 | 0.968 | 0.934–1.003 | 0.069 | 0.028 | −0.030 | 0.970 | 0.926–1.016 | 0.201 | 0.357 |
|                  | HAD Anxiety (0–21) | 167 | −0.051 | 0.950 | 0.862–1.047 | 0.301 | 0.009 | −0.059 | 0.943 | 0.826–1.076 | 0.382 | 0.360 |
|                  | HAD Depression (0–21) | 166 | −0.023 | 0.978 | 0.889–1.076 | 0.644 | 0.002 | −0.100 | 0.905 | 0.789–1.037 | 0.151 | 0.390 |
|                  | Self-Efficacy Scale (0–200) | 164 | −0.004 | 0.996 | 0.986–1.005 | 0.492 | 0.007 | −0.011 | 0.989 | 0.975–1.004 | 0.142 | 0.399 |
|                  | Tampa Scale of Kinesiophobia (11–44) | 165 | −0.038 | 0.963 | 0.908–1.020 | 1.97 | 0.014 | −0.031 | 0.969 | 0.897–1.047 | 0.430 | 0.374 |
| **Musculoskeletal physical** | NME, flexion (seconds) | 159 | −0.012 | 0.988 | 0.978–0.998 | 0.014 | 0.059 | −0.021 | 0.980 | 0.965–0.994 | 0.006 | 0.439 |
|                  | NME, extension (seconds) | 154 | 0.001 | 0.999 | 0.997–1.001 | 2.07 | 0.016 | 0.000 | 1.000 | 0.998–1.001 | 0.596 | 0.402 |
|                  | ROM, flexion (degrees) | 165 | 0.009 | 1.009 | 0.984–1.035 | 476 | 0.004 | −0.010 | 0.990 | 0.955–1.027 | 0.601 | 0.389 |
|                  | ROM, extension (degrees) | 165 | −0.010 | 0.990 | 0.965–1.015 | 418 | 0.005 | −0.011 | 0.989 | 0.956–1.023 | 0.512 | 0.394 |
|                  | ROM, flexion + extension (degrees) | 165 | 0.000 | 1.000 | 0.983–1.016 | 953 | 0.000 | −0.005 | 0.995 | 0.973–1.017 | 0.630 | 0.399 |
|                  | ROM, rotation right + left (degrees) | 165 | −0.018 | 0.982 | 0.967–0.998 | 0.028 | 0.042 | −0.023 | 0.978 | 0.955–1.001 | 0.056 | 0.402 |
| **Quality of life** | EQ-SD Index (−594–1 000) | 165 | −0.631 | 0.532 | 1.48–1.915 | 334 | 0.008 | −1.058 | 0.347 | 0.045–2.655 | 0.308 | 0.390 |
|                  | EQ-VAS (0–100 mm) | 166 | −0.007 | 0.993 | 0.978–1.003 | 354 | 0.007 | −0.025 | 0.975 | 0.953–0.998 | 0.030 | 0.426 |

* Adjusted for baseline measures; sex, age, WAD-level, Neck-Specific Exercise, Dizziness, and each separate predictor

Dependent variable, dizziness at 12 months; VAS visual analogue scale; NME Neck muscle endurance; ROM range of motion, HAD-A HAD-D hospital anxiety and depression scales, EQ-5D EQ-VAS EuroQol quality of life index
flexors (OR .99, 95% CI .97–1.00), showed significant association with the presence of dizziness at 12 months, based on the adjusted models. Indicating that the two predictors and the baseline covariates explain 50% of the variation in dizziness at 12 months. Noticeable is that the baseline covariates (predominantly age, dizziness and NDI at baseline) explain approximately 37% of the variation in dizziness at 12 months. The type of exercise intervention was not associated with the presence of dizziness 12 months post.

**Discussion**

The aim of this study was to first compare cervical related physical and psychological factors in individuals with and without dizziness, 12 months after commencement of a neck specific (with or without a behavioural approach) or general exercise intervention, and secondly to determine the combination of these factors to best predict those reporting ongoing dizziness. The results demonstrated that those who complain of dizziness in the long term, overall have significantly higher levels of pain and disability and poorer neck physical and psychological function, quality of life and static balance at baseline and at 12 months post-commencement of an exercise program compared to those not reporting these symptoms. Of these, the factors that best determined ongoing dizziness were age, baseline levels of dizziness and neck disability as well as less improvement in neck pain and disability and neck flexor muscle endurance at 12 months. The results of the study also confirmed that the symptom of dizziness is common in those with persistent WAD and was present in many participants, 12 months later despite some performing neck specific exercises previously shown to be favourable over general exercise for improving dizziness [12]. Overall these findings may have implications for future directions for management of persistent WAD.

**Dizziness**

The symptom of dizziness was frequent in those with chronic WAD before exercise intervention (73%) and at a 12-month follow-up (63%). Similar to those reported by Treleaven et al. [4]. Further, although the levels of dizziness were not marked and as high as people with diagnosed vestibular pathology such as Menieres disease [27], they are likely clinically relevant as they were on average at a higher level than those seen in people, for example, 6 months after acute vestibular loss [28] and similar to those with symptoms several years after acute vestibular loss [29]. This would suggest that the symptom of dizziness is clinically relevant and should be considered in those with persistent WAD and assessment and management specifically directed towards this. Interestingly 6% of the total cohort not reporting dizziness at baseline reported some dizziness at the 12-month follow up (Fig. 1). This may reflect the known yearly point prevalence of dizziness and the possibility of onset of dizziness from other causes [30]. Future work could consider the longterm epidemiology of dizziness post whiplash.

**The final multivariable model; NDI and NME flexors**

Although the change in scores from baseline to the 12-month post intervention follow-up in neck pain intensity, NDI, PDI, EQ-VAS and NME flexors were significant factors in the logistic regression, NDI and NME flexors were the remaining variables in the final model and together with age, baseline dizziness and NDI, explained 50% of the variance. These results strengthen the possibility of the role of disturbed cervical afferent input contributing to the cause of dizziness in some of the present.
population. This could mean that efforts directed towards reducing neck pain and disability and to exercise the cervical flexors may be important to reduce dizziness. Alternatively, this could suggest that the presence of dizziness inhibits the success of such interventions.

Interestingly neck extensor muscle endurance or muscle fatigability has been associated with greater balance deficits in WAD [7] which is often related with the symptom of dizziness [6]. In the current study though, neck flexors, not extensors, was a predictor for long term dizziness. Although, this may have been due to the method of testing with the extensor clinical test being highly variable with some people reaching long holding times [31]. In individuals with chronic WAD altered neck muscle interaction patterns of lower activity of the deep and an increased activity in the superficial neck muscles [32], and elongation of the deep neck muscles and a more stereotypic ventral movement pattern compared with healthy individuals has been identified [33]. Supporting the findings, neck-specific exercises have shown to improve ventral neck muscle interaction [34] and reduce dizziness, headache and health-related quality of life in chronic WAD and to be superior compared with general physical activity [12].

Alternatively, the results could indicate that the presence of dizziness for most may be a factor inhibiting response to exercise programs aimed at reducing neck pain and disability and improving neck muscle function. In the current study, the dizzy group only improved by about 1 second compared to 17 seconds in the non-dizzy group in flexion endurance and similarly no clinically relevant change in NDI (2%) was seen in the dizzy group compared to about 9% in the non-dizzy group. Similar findings with respect to the presence of dizziness and effectiveness of cervical management has been seen in those with cervicogenic headache [35]. A previous study also demonstrated a mild to moderate relationship between a change in dizziness intensity and NDI [12]. In this case, treatment directed towards dizziness would seem appropriate to assist recovery. Interestingly an occlusomotor rehabilitation program demonstrated improvements in balance and symptoms of dizziness in patients with chronic WAD but not neck pain intensity [36, 37]. Perhaps a multimodal approach with specific tailored sensorimotor control exercises in conjunction with local treatment directed towards neck specific exercises and improving neck pain will be required.

**Measures of sensorimotor control**
The results also suggest balance deficits remain regardless of symptoms of dizziness. The average sharpened Romberg score was lower in the dizzy compared to non-dizzy group. However, values for both groups suggest many participants may have deficits in this static balance test. Further, as balance is known to decline in association with vestibular and visual changes with ageing [38] it may be important to specifically assess and address this for falls prevention in this group, however, more research is required.

Head repositioning accuracy which is thought to be a measure of cervical proprioception, was not significantly higher in the dizzy group and on average was within normal limits, however, 46% of patients still had an abnormal score > 4.5 degrees in at least one direction of movement, which also supports a possible role of cervical proprioception as a contributor to dizziness in this population [39].

**Range of motion**
Those complaining of dizziness also had less total neck range of motion ($p = 0.001$) than those not complaining of these symptoms and especially regarding change in the horizontal planes ($R^2 = 0.042$). It is possible that this may be related to the presence of dizziness with movement or fear of motion [40] although scores of fear of movement were relatively low in both groups.

**Psychological factors**
Higher scores on a depression scale and poorer quality of life were identified in the participants with dizziness. Interestingly all of 12 participants identified as at risk of probable depression HAD D ($>10$) were in the dizzy group, although this only accounted for 13% of the participants in the dizzy group, suggesting levels of depressive symptoms are not generally high in those with WAD. Interestingly though, depression has been associated with persistent symptoms such as dizziness following acute vestibular loss [28]. Further, although, anxiety is usually associated with dizziness, [41] this not found in the current study. Whilst it is difficult to determine whether or not the psychological factors caused or worsened or were induced by the dizziness, high pain levels and dizziness have been previously identified as factors associated with initial and persistent depression in those with WAD [42]. The results of this study would concur with this finding.

Quality of life ratings were low (0.61) in the dizzy group after rehabilitation and similar to those post-surgery for cervical disc disease [43] and low compared to other illnesses such as (0.79) in patients with asthma [44]. This would indicate that more is to be done to improve quality of life and burden of the disorder in this group.

Mean results for pain catastrophizing (PCS) and fear of movement (TSK) were significantly poorer in the dizzy group but the mean scores for these questionnaires...
were low and likely not clinically relevant [45]. Similarly, although self-efficacy was significantly lower, mean values suggest this was not a main factor in this group.

**Strengths and limitations**
The current study used a strong design, had a long-term follow-up period and has large subject numbers in each group to allow for exploration of factors associated with dizziness 12 months post an intervention in those with WAD. However, the study can only assess relationships and the precise reasons for dizziness at 12-month follow-up cannot be ascertained. Regardless, certain factors (NDI and NME flexion changes) were associated with dizziness at follow-up in association with baseline variables of age, dizziness, or NDI. This may infer a possible cervical role in the presentation of dizziness but cannot determine the cause or causes of dizziness. Interestingly whether the group performed neck specific exercises or not was not a factor. This suggests further exploration is needed. Other measures that could be related to dizziness, such as overall health, and emergence or contribution of other causes of dizziness, such as vestibular pathology, should also be considered in future research.

**Conclusion**
The results of the study show that 63% of participants with persistent WAD had symptoms of dizziness, unsteadiness and deficits in balance and cervical proprioception, even 12 months post a specific neck- or general exercise program. This might be related to levels of change of NDI and NME flexion as well as baseline covariates. Pain and EQ-VAS were also factors of importance although not appearing in the final model. Alternatively, it may be that dizziness could be contributing to some of these signs and symptoms or have another cause. The results indicate a cervicogenic role in the production of dizziness in some and that intervention and rehabilitation specifically addressing neck-specific disability and NME flexion seem important. However, future directions should consider neck specific exercise with a multimodal approach, including tailored sensorimotor control exercises, as dizziness may be a factor inhibiting recovery in some individuals with persistent WAD. Future research should also explore other possible causes of dizziness in this cohort to assist management and reduce the ongoing burden and effects on quality of life.

**Abbreviations**
- WAD: Whiplash associated disorder; NDI: Neck disability index; NME: Neck muscle endurance; VAS: Visual analogue scale; UCLA: University of California Los Angeles dizziness score; RCT: Randomised controlled trial; OR: Odds ratios; CI: 95% confidence intervals; HRA: Head relocation accuracy; ROM: Range of motion; PDI: Pain disability index; PCS: Pain catastrophising scale; HAD: Hospital anxiety and depression; TSK: Tampa scale of kinesiophobia; SES: Self efficacy scale; EQ-SD: Quality of life.

**Acknowledgments**
We wish to thank all participants in this study, including WAD participants, physiotherapists and staff involved at any stage of the study.

**Authors’ contributions**
Treleaven, Peterson and Peolsson have given substantial contributions to the conception or the design of the manuscript, Landén Ludvigsson and Peterson for data acquisition, Treleaven and Peolsson for analysis and interpretation of the data. All authors participated in the initial drafting the manuscript, authors Treleaven, Peterson and Peolsson read and approved the final version of the manuscript. The authors read and approved the final manuscript.

**Funding**
The study was supported by funding from the Swedish government through the REH SAM foundation and the Medical Research Council, the regional Centres for Clinical Research of Östergötland, Regional Research Council Mid Sweden and Sörmland County Councils and the Medical Research Council of Southeast Sweden. Gunnel Peterson was supported by the Centre for Clinical Research Sörmland at Uppsala University Sweden and Regional Research Council Mid Sweden.

**Availability of data and materials**
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**
This study was a retrospective analysis of an assessor blinded prospective randomised controlled multi-centre study (RCT). Clinical trial NCT015228579 http://clinicaltrialsfeeds.org/clinical-trials/show/NCT015228579. The study was approved by the Regional ethical review board in Linköping, Sweden. Informed consent was gained from all participants and ethical procedures in accordance with the Regional ethical review board in Linköping, Sweden were maintained.

**Consent for publication**
Not applicable.

**Competing interests**
N/A The authors report no involvement in the research by the sponsor that could have influenced the outcome of this work.

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**Received:** 29 March 2022   **Accepted:** 5 July 2022

**Published online:** 18 July 2022

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