



Review

The effect of trunk muscle fatigue on postural control of upright stance: A systematic review

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ABSTRACT

Background: Fatigability and postural control deficits are both serious concerns in a variety of chronic musculoskeletal conditions. Research has shown that muscle fatigue may adversely affect postural control. This is while the evidence on the relevance of fatigue to postural control has never been summarized nor critically appraised. **Research question:** Is there sufficient and strong enough evidence to accept trunk muscle fatigue as a contributing factor to postural control alterations during upright standing posture?.

Methods: EMBASE, Scopus, ELSEVIER, PubMed, ProQuest, Google scholar and reference lists of the relevant articles were searched through April 2018. Studies having investigated the trunk muscle fatigue effect on postural control in asymptomatic individuals were included in the study. Only those studies having assessed postural control in terms of center of pressure driven variables were included.

Results: Twelve studies (218 asymptomatic participants) matched the inclusion criteria of this systematic review. Their results supported the hypothesis that fatigue has a significant effect on postural control in terms of the time domain variables. Sway velocity was consistently found to be affected by fatigue. The results were inconsistent in the frequency domain. The only study on the structural dynamics of center of pressure displacements also confirmed such a relationship.

Significance: The present review indicates that postural control is altered in asymptomatic individuals following trunk muscle fatigue. This may suggest that trunk muscle endurance training is crucial to address postural impairment in chronic spine musculoskeletal conditions.

1. Introduction

Optimal postural control is an essential prerequisite for safe performance during activities of daily living (ADL) [1]. Postural control involves integration of multiple sensory (visual, vestibular, and somatosensory) inputs within the central nervous systems where they are processed to plan and execute appropriate motor commands [2]. Deficits in the postural control system have been associated with musculoskeletal impairments [3]. The active element of postural control is mainly provided by muscular activation. Muscles have thus been considered as playing a critical role in spinal stability, postural control and balance [4,5]. Coordinated activation of the trunk muscles has been introduced as being necessary for maintenance of the upright quiet standing posture with minimal postural sway [6,7]. Alterations of the recruitment pattern of the trunk muscles has also been suggested to impose postural consequences challenging the stability of the spine [6,8,9]. Factors adversely affecting muscular performance may thus

challenge postural control and put the body at the risk of postural unsteadiness. Fatigue in the trunk muscles has been shown to induce more pronounced effects on postural control comparing fatigue in ankle, knee or shoulder regions [9].

Control of the erect posture during ADL requires sustained activation of postural muscles in an effort to generate and maintain low levels of force necessary to counteract external perturbing moments such as that of gravity. This is while, except in cases of extreme external perturbations, high levels of muscular activity are rarely required for the control of erect posture. This may explain why muscular endurance might be more crucial than muscular strength to spinal stability [10]. Among mechanical components, trunk and cervical extensor muscles endurance have been found most relevant to low back pain (LBP) [11] and neck pain [12], respectively. Muscle fatigue, defined as a decline in force or power output with the same or higher levels of muscle activation [13], has been proposed both as a perturbation to the postural control system [14] and a possible predisposing factor to

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musculoskeletal conditions. Higher rates of trunk muscle fatigue has been documented in patients suffering from LBP [15,16]. Muscular fatigue may disturb postural control by its adverse effects on the accuracy of sensory information [17], integration of peripheral afferents within the CNS [18] and efficacy of the motor commands recruitment [19].

Despite abundant theoretical and speculative explanations on the relevance of fatigue to postural control, to the best of the authors' knowledge, there are no systematic reviews to appraise the evidence on the effect of local trunk muscle fatigue on the control of erect standing posture. This is while a variety of chronic musculoskeletal conditions such as LBP and NP have been attributed to poor postural control and it merits clinical significance to summarize the evidence on the relevance of trunk muscle fatigue to postural unsteadiness. The results might have implications on designing rehabilitative protocols for the prevention and management of such conditions. Documenting the association between muscular fatigue and postural control impairment will help to predict if endurance exercises might be beneficial reversing postural deficits in chronic LBP or NP cases.

The aim of the present systematic review was to determine the effect of trunk muscle fatigue on postural control by critical analysis of the literature and to evaluate its level of evidence.

2. Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines [20].

2.1. Search strategy

Six electronic databases: “EMBASE, Scopus, ELSEVIER, PubMed, Web of Science and Google scholar” were searched for the published papers from inception until April 2018. The reference lists of the relevant papers were also explored for any extra papers not found during the primary electronic search. The search strategy used were combinations of the following search keywords: “low back”, “lumb*”, “trunk”, “torso”, “back”, “spine”, “fatig*”, “exhaustion”, “lassitude”, “tired”, “burnout”, “postural control”, “postural steadiness”, “postural stability”, “postural sway”, “postur*”, “COP”, “center of pressure”, “sway”, “balance”, “equilibrium”, “force plat*”. The specific search strategy for PubMed database is provided in Appendix A.

2.1.1. Selection criteria

Included papers were limited to those published in peer-reviewed journals without language or publication date restrictions. Original research papers having investigated postural control through COP driven measures, comparing the local pre/post trunk muscle fatigue conditions (in terms of EMG signal median frequency or force reduction) in symptom-free subjects were included in this review. Experiments including generalized fatigue or postural control measures other than COP parameters were excluded.

2.2. Data extraction

The following information was extracted from the included full-text articles: the authors' name, study design, year of publication, characteristics of the samples including the age, number and gender of participants, fatiguing task, conditions in which postural control was assessed, COP driven measures and key findings.

2.3. Quality assessment

All relevant studies were assessed using a quality assessment checklist. This checklist includes relevant criteria obtained from National Institute for Health and Care Excellence (NICE) [21], National

Institute of Health (NIH) [22], Hailey's criteria [23] and Critical Appraisal Skills Programme (CASP) System for Case-Control studies (Public Health Resource Unit) [24] giving a total of 15 criteria to be assessed in cross sectional studies. When there was inadequate information on internal validity of the articles, the corresponding authors of the studies were contacted for further information. Papers having fulfilled less than 50% of the criteria were rated as “low”, those with 50–75% fulfillment as “moderate” and those obtaining more than 75% of the scores as “high” quality.

The search process, paper scanning for the selection criteria and quality assessment were all performed by both authors independently. Disparities were resolved by discussion and final decision was reached through consensus. In cases of considerable disagreement a third colleague would be consulted.

3. Results

3.1. Literature search results

The electronic databases search provided 824 (580 after duplicates removal) studies the abstracts of which were screened for inclusion criteria. No additional studies were identified through hand-searching of the reference lists of the relevant studies. The remaining articles were further explored through screening titles and abstracts and application of inclusion/exclusion criteria. Five hundred and forty two articles were removed by their titles and 20 by their abstracts. Only 18 studies successfully met our inclusion/exclusion criteria the full texts of which were reviewed by both authors independently. Six of these studies were also excluded during further evaluations: three studies had investigated balance [25,26] and postural strategy [27] without using COP parameters; in two studies [28,29] general fatigue was examined and in the other study postural control scores of the post fatigue condition were not clearly reported [30]. Subsequently, 12 studies met the inclusion criteria [8,9,31–40] and entered the quality assessment phase of our systematic review (Fig. 1).

3.2. Description of included studies

The characteristics of the included studies have been summarized in Table 1. All studies were published between 2004 and 2018, and were in English. Totally, 218 asymptomatic subjects had participated in these studies. In five studies [6,8,32,34,39], both sexes were included (women: 55; and men: 49), whereas in four studies [33,35,38,40] only male subjects were included and in three other ones [9,36,37] the sex of the participants were not reported. The asymptomatic subjects were defined as not presenting musculoskeletal or neurological disorders and vestibular impairment. In two studies [34,41], no history of cardiovascular or respiratory disease was also noted. In ten of the studies, fatigue was induced by isotonic trunk muscle contraction while in two other studies [6,8] isometric activity of these muscles were used to induce fatigue. In all studies except one [31] (having fatigued both flexor and extensor groups) fatigue was imposed on trunk extensor muscles. In seven of the studies [6,8,9,36–38,41] fatiguing contractions were continued until exhaustion while in the other 5 [33–35,39,40] force reduction to a fraction (60–86%) of the maximum voluntary exertion (MVE) was set as the fatigue index. Table 2 shows the details of the fatigue protocol in the included studies. Static standing (upright [8,9,31,37,38,40] or forward bent [39]) postural control was assessed in all included studies (Table 1). While all studies (except one) assessed COP time domain measures, three of them also included frequency domain parameters [33,36,41] and one utilized structural analyses to describe COP behavior [39].

3.3. Outcomes

Overall, all the included studies reported a significant effect for

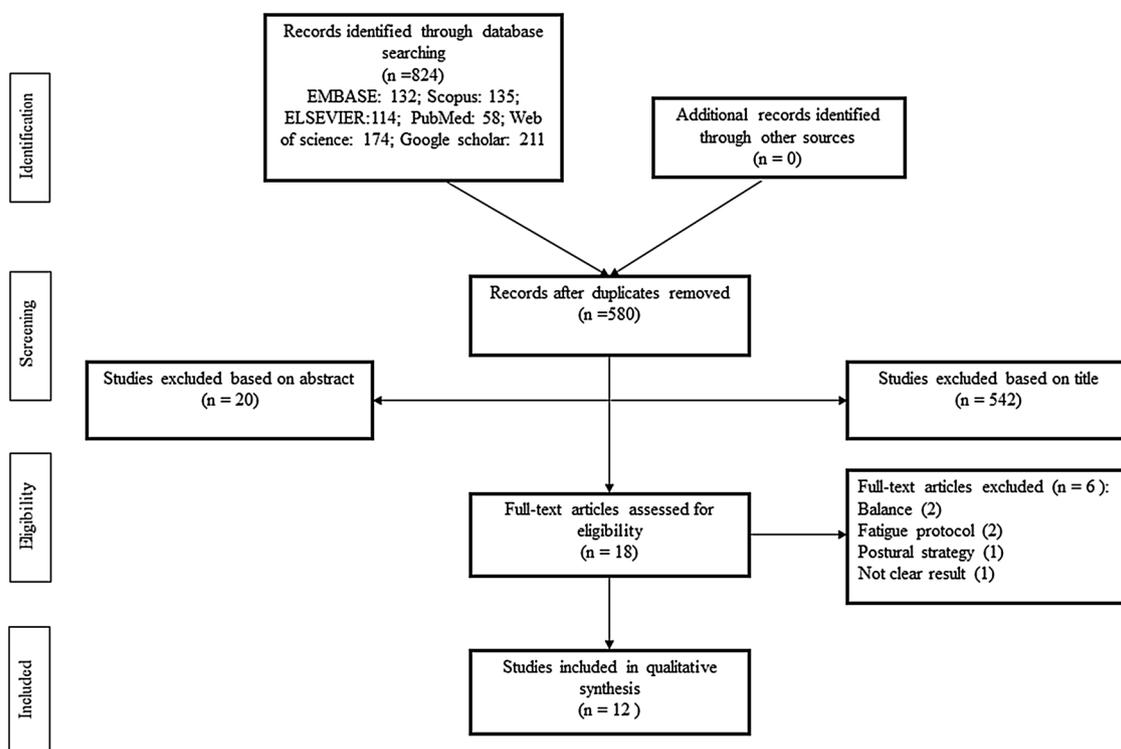


Fig. 1. PRISMA flow chart of study selection process.

fatigue on COP driven measures in the time domain variables, but the results were inconsistent in the frequency domain. Among temporal variables, sway velocity was consistently found to be affected by fatigue in all but four studies [8,37–39]. Increase of the mean and peak velocities were reported in five [9,33,37,40,41] and two of the studies [34,40], respectively. Madigan et al. found the variability of velocity measure to be augmented following fatigue [35] while in Larson et al.'s study, root mean square (RMS) velocity and velocity ranges were found to be increased in response to both extensor and abdominal muscles' fatigue [6]. Pline et al. showed a positive correlation between peak sway velocity and the level of trunk extensor fatigue [40]. Three studies investigated the effect of fatigue on the variability measures of COP position and the results were controversial. While Madigan et al. reported decreased COP position variance [35], Vuillerme et al. found COP displacements to become more variable following trunk muscle fatigue in 2 independent studies [36,38].

Among the three studies investigating frequency domain parameters, two found no significant alterations in response to fatigue [33,41] while one reported higher median and RMS frequency [36]. Granata et al. investigated fatigue effects on postural control mechanisms using analyses of non-linear dynamics. They reported significantly larger maximum Lyapunov exponent values and smaller embedding dimension in the phase portrait [39] indicating decreased dynamic stability and complexity, respectively. Two studies investigated the effect of fatigue rate and/or level on postural control alterations [35,40]. One revealed that increasing fatigue level and time will augment postural responses [40], but the other one did not report anything about the effect of different fatigue levels on postural control [35].

3.4. Methodological quality of the included studies

All included studies except one [39] were rated as high quality (quality score > 70%) with the scores presented in Table 3. Critical appraisal found the articles to be methodologically heterogeneous and meta-analysis of the data was thus not possible. Common areas of bias were small sample size and lack of measurement reliability reporting in

almost all studies except one [34]. Of the 11 corresponding authors who were contacted, three replied to our inquiry about reliability reporting none of which having performed reliability measurement [9,35,41]. The sample size was small in all studies (ranging from 10 to 36) and there was no justification rationale for that except in one study [8].

4. Discussion

This systematic review revealed that trunk muscle fatigue is a challenging condition for postural control. While there is so little and inconsistent evidence on the effect of fatigue on frequency domain parameters, time domain COP measures have almost consistently been found to be affected by trunk muscle fatigue.

Increased mean, peak and variability of COP velocity was reported in the majority of the studies, all of which rated as high quality. A significant positive relationship was reported between trunk extensor muscles' fatigue level and time and sway velocity in one study [40]. Longer fatigue duration and higher fatigue level may result in creep in trunk muscles viscoelastic connective tissues shown to be associated with impaired trunk control [42], and suggested to contribute to increased COP displacement [40]. It has also been argued that increasing fatigue level may increase muscle force fluctuations that might in turn augment trunk movements and postural sway [40]. COP velocity, among all other COP variables, has been introduced as the most accurate balance parameter characterizing postural control [43,44], valid in detecting changes in postural steadiness [45] and has the greatest intra-participant consistency [46].

Multitude of explanations for the effect of muscles' fatigue on postural control can be categorized as peripheral and central mechanisms. The peripheral sensory and motor nerves, neuromuscular junction and muscle fibers constitute the peripheral motor system. Impaired functioning of any of these components leading to physical performance decline following sustained or repeated motor activity is assumed as peripheral fatigue [47]. Decreased proprioceptive accuracy of trunk muscles following fatigue has been proposed as a potential contributor to fatigue-induced postural control deficits [48,49]. Since proprioception

Table 1
The description of the included studies and their findings on the effect of fatigue on postural control.

Author (yrs)	Participants	Fatigue protocol	Testing Procedure	Outcome measures	Results
Larson et al. [31]	Healthy (N = 10, f = 5), age: 23 ± 2.2 yrs	Isometric Ext/ Flex	60 s double leg stance on the foam, EC	COP dx. and velocity ranges, RMS dx. and velocity in AP and ML directions, path length	AP RMS velocity, path length post-fatigue of the trunk extensor muscles. AP dx. range, AP RMS dx., AP and ML velocity ranges, ML velocity RMS after both trunk extensor and abdominal muscle fatigue
Parreira et al. [32]	Healthy (N = 36, f = 18) (young: N = 18, f = 9, age:18-30 yrs) (elderly: N = 18, f = 9, age > 65 yrs)	Isotonic Ext	30 s one leg stance, EO	Ellipse area, RMS AMP, mean velocity, mean frequency in AP and ML directions	Mean COP velocity in both directions in elderly subjects. Mean COP velocity in ML direction in young subjects.
Johanson et al. [8]	Healthy (N = 16, f = 11), age: 22.17 ± 1.7 yrs,	Isometric Ext	60 s double leg stance on the foam and firm surfaces with TS and MF muscles vibration, EC	RMS and mean values of COP position in AP direction, RW TS/MF	RMS, anterior sway following MF vibration and posterior sway following TS vibration on the foam surface, RW TS/MF on the foam surface. Peak COP velocity, Peak dx.
Davidson et al. [34]	Healthy (N = 32, f = 16), (young: N = 16, f = 8, age:19.4 ± 1.4 yrs) (older: N = 16, f = 8, age:62.2 ± 5.1 yrs)	Isotonic Ext	Perturbations at 4 N s and 2 N s below the maximum perturbations withstood by the participants	Peak dx., time to peak dx., peak velocity, time to peak velocity, minimum time to boundary, time to return to 20% peak dx.	Ellipse area, mean AP velocity, AP COP-COM, 5th percentile time to boundary.
Lin et al. [9]	Healthy (N = 32, sex=?), (young: N = 16, age:18-24 yrs)(older: N = 16, age: 55-65 yrs)	Isotonic Ext	75 s double leg stance, EC	Ellipse area, mean velocity, time to boundary, detrended fluctuation analysis exponent, instantaneous scalar distance between COP and COM, RMS COP - COM	Embedding dimension, λ_{max}
Granata et al. [39]	Healthy (N = 10, f = 5), age: (m = 29.6 ± 5.2), (f = 23.6 ± 4.5) yrs	Isotonic Ext	30° trunk flexion to touch a target for a duration of 1 min	Embedding dimension, λ_{max}	COP surface area, variance of the COP position in AP and ML directions
Vuillierme et al. [38]	Healthy (N = 10, m), age: 25.2 ± 3.2 yrs	Isotonic Ext	30 s double leg stance with and without feedback, EC	Surface area, variance of the COP position in AP and ML directions	Surface area, mean velocity, variances of positions (in both axes), RMS frequency in both axes, median frequency in the Cop-CoGv motions.
Vuillierme et al. [36]	Healthy (N = 15, sex=?), age: 21.3 ± 1.1 yrs	Isotonic Ext	30 s double leg stance on the foam and firm surfaces with and without tactile stimulation, EC	RMS frequency, median frequency along AP and ML axes of COP-CoGv. Surface area of COP	Surface area on both the firm and foam surfaces as well as in the tactile and no tactile feedback conditions.
Vuillierme et al. [37]	Healthy (N = 20, sex=?)(N = 10, age: 26 ± 5.6 yrs) (N = 10, age:24.5 ± 4.2 yrs)	Isotonic Ext	32 s double leg stance on the foam and firm surfaces with and without tactile stimulation, EC	Surface area of COP	Mean and peak sway velocity. Peak sway velocity was higher in high-level fatigue (60% MVE) compared to low-level fatigue (86% MVE).
Pline et al. [40]	Healthy (N = 12, m), age: 20-22 yrs	Isotonic Ext	30 s double leg stance, EC	Mean velocity, peak velocity, sway area	Anterior shift in COP position. SD of COP position in ML direction. SD of COP velocity in both AP and ML directions.
Madigan et al. [35]	Healthy (N = 12, m), age: 20-22 yrs	Isotonic Ext	30 s double leg stance, EC	COP position, COP velocity, SD of COP position and velocity in AP and ML directions.	Mean velocity, modified ellipse area, sway area.
Davidson et al. [33]	Healthy (N = 13, m), age: 20-22 yrs	Isotonic Ext	30 s double leg stance, EC	Mean velocity, peak velocity, modified ellipse area, sway area, mean and median frequency in AP and ML directions	

AMP: amplitude, AP: anterior-posterior, COG: center of gravity, COM: center of mass, COP: center of pressure, dx: distance, EC: eyes closed, EO: eyes open, Ext: extension, f: female, Flex: flexion, m: male, λ_{max} : maximum Lyapunov exponent, MF: multifidus, ML: mediolateral, MVE: maximum voluntary exertion, RMS: root mean square, RW: re weighting, min: minute, s: second, SD: standard deviation, TS: triceps surae, yrs: years.

Table 2
Description of fatigue protocol in each of the included studies.

Author (yrs)	Subject Position	External resistance	Task	Target fatigue measure
Larson et al. [31] Parreira et al. [32]	Prone/ Supine 45° Roman chair	No Equivalent to 40-60% MVE	Isometric Ext./ Flex. Isotonic ext. from 45° Flex. paced at a rate of 2 s for each, performed 1 cycle/ min	Exhaustion Exhaustion. Not able to maintain the movement velocity during 3 consecutive cycles Exhaustion 70% MVE
Johanson et al. [8] Davidson et al. [34]	Prone Standing	No 45% MVE	Isometric Ext. Isotonic Ext. from 45° Flex. paced at a rate of 23/ min performed 1 set for a total duration 14 min	Exhaustion 70% MVE
Lin et al. [9] Granata et al. [39]	Standing 45° Roman chair	If necessary No	Isotonic Ext. at 60% MVE from 45° Flex paced at a rate of 12/ min Isotonic Ext. from 60° Flex., 10 repetition at a rate of 30 cycles / min for a total duration 16 min	Not able to perform Ext. over the entire ROM for 3 reps 60% MVE
Vuillerme et al. [38] Vuillerme et al. [37] Vuillerme et al. [36] Pline et al. [40] Madigan et al. [35] Davidson et al. [33]	Prone Prone Prone 45° Roman chair 45° Roman chair 45° Roman chair	No No No No No No	Isotonic Ext. from 90° Flex. as many times as possible Isotonic Ext. from 90° Flex. (mean dur 54 s) as many times as possible Isotonic Ext. from 90° Flex. (mean dur 54 s) as many times as possible Isotonic Ext. from 60° Flex. for a total duration 14 and 90min Isotonic Ext. from 60° Flex. paced at a rate of 1 set/ min for a total duration 14 min Isotonic Ext. from 60° Flex. paced at a rate of 1 set/ min for a total duration 10 and 90 min	Exhaustion Exhaustion Exhaustion 86%, 73%, 60% MVE over 14min, 73% MVC over 90 min 86%, 73%, 60% MVE 60% MVE

Ext: extension, Flex: flexion, MVE: maximum voluntary exertion, min: minute, ROM: range of motion, s: second, yrs: years.

impairment has been associated with chronic musculoskeletal conditions such as chronic LBP [50], fatigue-induced postural deficits might be explained by impaired proprioception in such conditions. Impaired proprioception from the trunk muscles might result in poor control of the lumbar spine kinematics and delay the stabilizing muscle activation necessary to generate postural corrections [33]. Neural transmission has also been found to be slowed in fatigued condition [51]. This may result in both delayed sensory afferents to the central processing units of the postural control system and late motor commands to the actuator muscles. Delayed corrective adjustments by the postural muscles may result in less controlled postural sway. Besides neural transmission impairments, reduced muscular force generating capacity following fatigue might adversely affect postural control [52,53]. Lactic acid accumulation, interfering with troponin to Ca⁺⁺ binding [25,54], might be considered as an explanation for reduced muscle contractile capacity following fatigue, which may result in impaired postural control [55,56].

Central fatigue, defined as decline in voluntary activation of the motor system decreases motor output from primary motor cortex (M1) via supraspinal mechanisms [57]. Alterations in the sensory input from the peripheral system following fatigue have been suggested to activate inhibitory interneurons limiting the motor output [58]. Central mechanisms have been accounted for 20–25% of the force loss following fatigue [59] interfering with postural control. M1 cortex has been proposed to contribute to the control of postural sway during both unperturbed standing [60] and complex postural conditions [61], which further indicates that central mechanisms contribute to altered postural control following fatigue.

4.1. Study strengths and limitations and recommendations for future research

This review focused only on studies reporting effect of trunk muscle fatigue on COP driven measures. Since trunk muscle fatigue, in comparison with fatigue in other regions, has been shown to have more pronounced effects on postural control [9], and to avoid heterogeneous evidence, we decided to exclude studies on the effect of general fatigue or fatigue in other regions. It should also be mentioned that while we limited our investigation to the studies including COP parameters, there are some other measures characterizing postural control such as kinematic alterations of the lower limb joints and global balance measures such as star excursion balance tests score and Biodex balance scale. To avoid data heterogeneity, we decided not to include all these measures, which imposes limitations to the generalizability of our results. The search strategy was not limited by language, but some relevant studies from the gray literature might be missing. Meta-analysis was not possible due to poor homogeneity of fatigue protocol and outcomes measures. The methodologies of almost all included studies were rated as high quality.

Small sample size and lack of sample size rationale and measurement reliability reporting almost consistently constituted internal validity issues of the studies increasing the risk of bias. Almost all included studies investigated COP alterations in the time domain and there is lack of sufficient evidence on COP changes in the frequency domain or COP signal structural alterations assessed by nonlinear tools. Postural control [62–64] and trunk muscle fatigue [16,65] are both important concerns in chronic musculoskeletal conditions such as CLBP, but too few investigations on the effect of trunk muscle fatigue on postural control in these patients did not provide the opportunity to conduct the systematic review on such studies. The results of the current review highlights the necessity for conducting investigations on the mechanisms by which fatigue might contribute to postural control deficits in chronic musculoskeletal conditions such as CLBP.

Table 3
Quality assessment of the included studies.

	Larson et al. [31]	Parrera et al. [32]	Johanson et al. [8]	Davidson et al. [34]	Lin et al. [9]	Granata et al. [39]	Vuillerme et al.[38]	Vuillerme et al.[36]	Vuillerme et al. [37]	Pine et al. [40]	Madigan et al. [35]	Davidson et al. [33]
Clear statement of the research objective or question	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use of an appropriate method to answer research question	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Clear specification of the study population	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Prespecification of the inclusion/exclusion criteria and their uniform application to all participants	✗	✓	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗
Sample size and its justification rationale	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Outcome measures description	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reliability assessment of the measurements	NR	✗	NR	✗	✗	NR	NR	NR	NR	NR	✗	NR
Confounding factors control	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Proper use of statistical tests	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Missing results	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thorough and clear reporting of the results	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Precision of the results	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Statistical summary	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Consistency of the conclusions and the presented data	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total score	10	11	10	12	11	8	11	10	10	10	10	10

NR: not reported, ✓: most sub-items successfully fulfilled without any important factor violated, ✗: most sub-items or an important one failed.

5. Conclusions

The findings of the current systematic review indicate that, trunk muscle fatigue could be a contributing factor to postural control alterations in asymptomatic participants. COP velocity was found to be the most sensitive COP driven measure for fatigue induced postural alterations. Further investigations on the effect of trunk muscle fatigue on postural control are recommended in chronic musculoskeletal conditions such as CLBP in which higher rates of fatigue and postural control deficits are both concerns.

Declarations of interest

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Appendix A. Supplementary data

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