



## Prevention and Rehabilitation

## What we know so far about postural balance training: An exploratory scoping review of nomenclature and related issues

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## ABSTRACT

**Background:** Different terms are used to refer to postural balance training, but the ontological debate involving the concepts to pursue nomenclature consensus is unusual.

**Objective:** The goal of this study was to analyze how often the terms *balance*, *neuromuscular*, *proprioceptive*, *functional* and *sensorimotor training/exercise* are used in the literature, and to propose a conceptual critical appraisal to determine the most appropriate terminology to address postural balance exercises.

**Methods:** A literature search was conducted in the Scopus electronic database. **Eligibility criteria:** papers with the selected expressions on the title or keywords, published in English, were included.

**Results:** The most used term was balance training (471 of 1105 included papers). Europe, followed by Asia and North America, had the highest number of publications. In the 21st century, the number of publications increased considerably. However, the terms have conceptual differences and controversies regarding its use.

**Conclusion:** Despite a large variety of exercise types and divergences, *balance training* seems to be the most suitable term, given it refers to postural equilibrium exercises.

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## 1. Introduction

Postural balance can be defined as a complex motor task that requires central processing of different sensory inputs (somato-sensory, vestibular and visual cues), selecting adequate body strategies and muscle activity patterns to keep the center of mass projected within safety limits of the support base (Massion, 1994; Ragnarsdottir, 1996). Horak (2006) states that the two main functional goals of postural control are postural orientation and equilibrium. Postural orientation is involved in body alignment with respect to gravity, support surface, visual environment and internal references (Horak, 2006). In turn, postural equilibrium involves the coordination of sensorimotor strategies to stabilize the center of

body mass during both self-initiated and/or externally triggered disturbances (Horak, 2006). Moreover, expectations, goals, prior experience, cognitive tasks, emotional context, and the environment also interfere with this process (Horak, 2006; Visser et al., 2008).

In practice, exercise programs with balance-specific tasks seems to lead to a decrease in the spinal reflex excitability and the cortical contribution, which imply higher subcortical participation in balance control (Taube et al., 2008; Rogge et al., 2019). In addition, balance training improves postural control through activities that challenge the body stability, mainly in standing posture (Lesinski et al., 2015). Although acute exercises can disturb balance by degrading the effectiveness of sensory-motor integration of the postural control, the chronic balance training seems to improve the postural adjustments by inducing positive functional adaptations in the postural balance (Paillard, 2017).

Balance exercises have been widely adopted for improving

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postural control as a strategy to prevent musculoskeletal injury in sports training (Zech et al., 2010), motor rehabilitation (Sefton et al., 2011; Gioftsidou et al., 2012), and fall prevention programs (Halvarsson et al., 2012; Rogers et al., 2013; Low et al., 2017). Despite the important debate in the literature about the functional and anatomic changes and about the exercises and the volume of training most indicated for balance training in healthy individuals or with different conditions of functional impairment (Gebel et al., 2018; Kiss et al., 2018; Low et al., 2017; Behm et al., 2015; Lesinsky et al., 2015), there seems to be a lack of dialogical and interdisciplinary debate about the conceptual issues.

Different terms, such as *balance training*, *sensorimotor training*, *neuromuscular training* and *proprioceptive training* (Taube et al., 2008; Kim et al., 2011; Rogers et al., 2013), and *functional training* (Abbasi et al., 2012) are commonly used to refer to those exercises usually recommended for improving postural balance. However, despite the widespread use of such terms in the literature, the debate about the scope and appropriateness of them is not so frequent (Taube et al., 2008). Kim et al. (2011), for instance, highlighted the lack of consensus regarding the use of these terms, because many authors use these different terms as synonyms or to address the same type of exercise, and there are also disagreements about the relevance of a certain term for a particular balance exercise.

Kim et al. (2011) observed that the expression *proprioceptive training* is associated with balance, plyometric, agility and strength exercises that have some balance component. They argue that proprioceptive training is a clinical concept to be used for rehabilitation exercises. In addition, these authors consider that proprioceptive training evolved from traditional bodyweight transfer exercises to tasks on unstable surfaces that create a challenging environment, rich of sensory stimuli for the proprioceptors, as well as for the entire central nervous system. In turn, Ogaard (2011) suggests that the term proprioceptive training should only be adopted for exercises performed on stable surfaces, while Cimino et al. (2010) suggest that “neuromuscular or proprioceptive training” [as synonymous] should only be addressed to the improvement of muscle reflex responses.

Furthermore, according to Kim et al. (2011), the researcher's area can potentially influence their definition of terms, resulting in a wide range of terms and concepts used for postural balance training. Rogers (2010) also reinforced that the field of study influences the selection of terms, arguing that *functional training* has become popular in the fitness field, where this training modality is considered a very important trend in this industry. However, Rogers (2010) considered the term suitable when the exercise aims to promote “physical ability to perform daily activities safely and independently, without fatigue”. Another important issue is that terms such as *proprioceptive training*, *sensorimotor training*, *functional training* and *neuromuscular training* are used not only to refer to balance training but also are used with other meanings. The term *functional training*, for instance, is used for exercises aiming to restore temporomandibular function after mandible fracture (Feng et al., 2009) or upper limb fine motor skills (Byl et al., 2008). In addition, the term neuromuscular training was used as synonymous for resistance training exercises with a vibrating weight (Tripp et al., 2009). Thus, given the variety of exercises identified by the same terms and the number of terms to address the same type of exercise, few authors engage in a critical debate about the adequacy of the nomenclatures commonly adopted in the clinical and exercise routine.

The choice of terms and concepts should be closely linked to the exercise nature, as an ontological issue. The American College of Sports Medicine (ACSM) structured the physical fitness in health- and skill-related components, where balance is mentioned as a

motor skill (ACSM, 2018), due to a complex control system. Taube et al. (2008) argued that the use of general terms like *sensorimotor training* is inappropriate, as they consider that the sensorial and motor systems involved in balance are also systems involved in other motor tasks. The term *functional training* has the same issue, and it is used to refer to exercises to improve postural balance (Abbasi et al., 2012), but also to address daily living activities (Peterson, 2017). On the other hand, considering postural control as conducted by a complex dynamic process involving many integrated biological systems, Taube et al. (2008) reported that terms pointing out to a specific system – as *proprioceptive training* – disregard the adaptation of other parts of the control system involved during the same training. In line with the ACSM (2018), Taube et al. (2008) concluded that *balance training* is the most appropriate term to be used to programs or exercises aimed at improving postural control based on body instability, because *balance* means the ability to be improved and does not disregard the complexity of the control system involved in that function.

The ontological debate about the essence of the balance training, in function of the complexity of the postural control system, and the need to consider this complexity to better prescribe a training or treatment program are fundamental to understand how experiences during balance exercises challenges and makes possible exercise progression, instead of using only intuition or expertise. A relevant issue to start this debate is related to the nomenclatures and concepts involved, and the understanding of how often the terms are used and how they emerge and resist through time, which can indicate its consolidation in the scientific field.

Therefore, the aim of the present study is to (re)start the debate by analyzing the frequency of use of the different terms cited in the scientific literature to address postural balance training (*balance*, *neuromuscular*, *proprioceptive*, *functional* and *sensorimotor training/exercise*) in relation to conceptual inconsistencies, contradictions, pitfalls and disagreements that are not necessarily in a dialogical process contributing to this debate.

## 2. Methods

A comprehensive search strategy was performed on January 2018 using the SCOPUS database. Thus, a scoping review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). The search was performed for two researchers using the following terms, between parentheses and the boolean operator “OR”: *balance training*; *balance exercise*; *sensorimotor training*; *sensorimotor exercise*; *neuromuscular training*; *neuromuscular exercise*; *proprioceptive training*; *proprioceptive exercise*; *functional training*; *functional exercise*. The inclusion criteria in this study were: original papers (articles or conference papers published in journals or conference proceedings) written in English, containing at least one of the terms of interest in the title or keywords. These criteria were set using the Scopus database filters.

All papers were inspected by the researchers and, in case of divergence, they were re-analyzed by the co-authors of the study. The exclusion criteria were: animal studies, review articles, and respiratory studies using the broader term *functional exercise capacity* in the title and/or keywords.

The choice for search strategy based on the title and keywords is justified by our interest in the expressions that the authors consider the most suitable as descriptors of their work. Review papers were not considered because they compile data from other articles and they can use different terms, even if the terms were not those the authors consider the most suitable for searching. Further, the year

of publication was not restricted to more recent papers in order to allow a temporal analysis. We did not conduct a research quality analysis of the papers selected, because we were interested in the frequency and in the context in which the terms are used and not in the efficacy of a given training method. Five researchers were responsible for the data extraction, including the two who conducted the review process. All the terms found were independently analyzed and organized by at least two researchers that identified the title, list of authors, authors' affiliations with their geographical regions, the year of publication, the name of the journal where it was published, the type of paper and the presence of terms of interest in the title and/or keywords.

Data were tabulated and then processed to provide the frequency distribution of terms and their location (i.e. title, keyword or both). The studies' geographical distribution and year of publication provided information about the use of terms over the decades for scoping review.

### 3. Results

The review process yielded a total of 1727 papers. From this total, 622 were excluded (most of them did not have the term of interest; 11% were pulmonary capacity studies using the term *functional exercise capability* and less than 1% were about animal or duplicated studies). A total of 1105 articles remained and were included in the final analysis (Fig. 1). Fig. 2 shows the relative distribution of the terms.

Data showed the words *balance*, *proprioceptive*, *sensorimotor*, *neuromuscular* and *functional* as more frequently associated with the term *training* than with the word *exercise*, both when found in the Title and in the Keywords. In addition, terms containing the words *balance* and *functional* were more frequently used than those with the words *proprioceptive*, *sensorimotor* and *neuromuscular* (Fig. 2). Moreover, terms were found with more frequency in the title than in the keywords. Most of the papers use only one main term (i.e. *balance*, *proprioceptive*, *sensorimotor*, *neuromuscular* or *functional*), and only few papers associated them with either training or exercise simultaneously. Only 32 papers presented more than one main term (Fig. 1).

The frequency of the terms *balance*, *proprioceptive*, *sensorimotor*, *neuromuscular* and *functional* being used in association with either *training* or *exercise* changed over the years and increased in the last decades (Fig. 3).

The oldest study found was published in 1940. The temporal analysis suggests that the term with the longest use is *functional* [training or exercise]. The term *balance* [training or exercise] seems to be used initially in the 1950s, but not during the 1960s and 1970s, returning in the mid-1980s. In turn, the term *proprioceptive* [training or exercise] appeared in the mid-1990s, while the terms *neuromuscular* [training or exercise] and *sensorimotor* [training or exercise] seem to be first used in 1978 and 1979, respectively.

The frequency increased for almost all terms in the last years of the 1990's and subsequently in the 21st century. In the 1990's, the terms *sensorimotor* and *proprioceptive* were not commonly used, but they preserved some regularity. In turn, the use of the term *neuromuscular* has increased especially in the last decades, but the terms *functional* and *balance* showed the highest frequency.

Regarding the papers' geographical distribution over the decades, some of the earlier studies could not be related to any country due to lack of information about authors' affiliation (Fig. 4). In these cases, when authors' affiliations at that time were not found on the web, the continent was not considered and the register was presented as undetermined geographical region. The first studies were from North America and Europe. After that, in the 1980's, some articles from Oceania were also found. The production

of papers with these terms in Asia emerges in the 1990's, and in South America and Africa only after the year 2000.

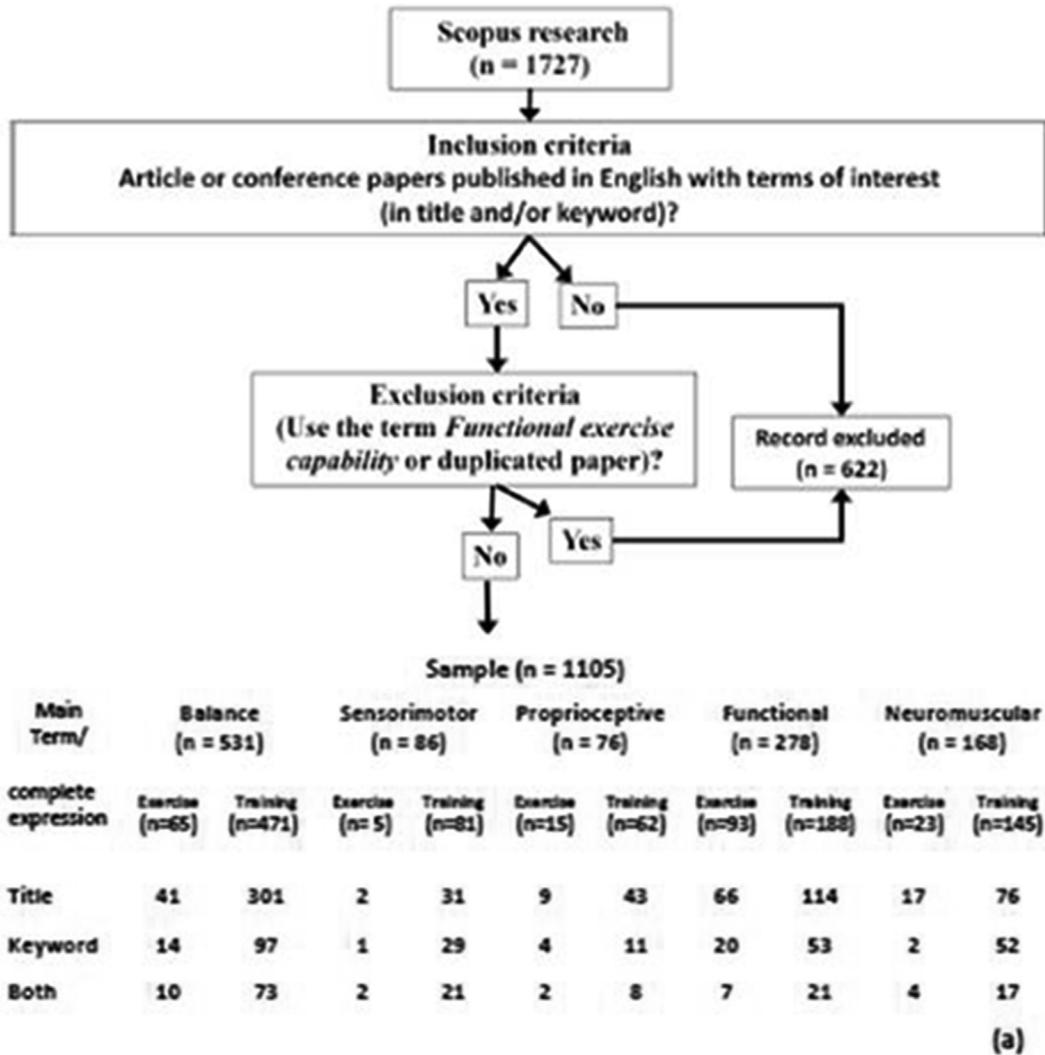
Taken together, Europe, Asia, and North America provided, respectively, the higher quantity of studies with the searched terms. In the last decade, Asia surpassed North America in number of publications. Oceania, South America and Africa have increased their research contribution in the last two decades, but remain well behind the first three. Central America and Africa are the regions with less published papers in our search.

### 4. Discussion

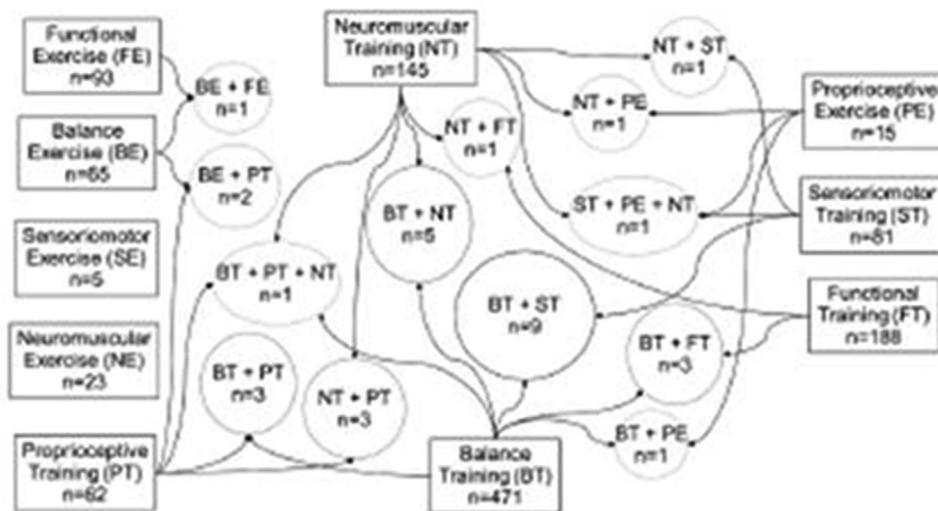
Several studies have been conducted aiming to better understand how exercises influence postural control under different conditions and with different populations. Considering the diversity of exercises, protocols and populations used in balance training research, Low et al. (2017) have concluded that balance exercises, but not strength or multicomponent exercises, improve postural control. Behm et al. (2015) showed the benefits of strength exercises performed on stable and unstable surfaces on strength, power, and balance at different stages of life. However, the effects on strength parameters were higher in young people and the effects on balance were more pronounced in the elderly. Nonetheless, results were inconclusive when strength exercise on stable and unstable surfaces were compared and the authors considered that there was no extra effect linked to the surface stability. Kiss et al. (2018) compared balance across the life span and found a small correlation between types of balance and stage of life. Lesinsky et al. (2015) also pointed out the ideal period and frequency of training to improve balance performance in healthy older subjects. In addition, these same parameters did not have an effect on balance performance on youth (Gebel et al., 2018). Gebel et al. (2018) suggested the need to identify the factors related to performance and the basic concepts that are important to clarify and better understand the "unidentified factors" in this context. Kummel et al. (2016) conducted a meta-analysis about the specificity of training and showed that balance training can improve the performance in trained tasks, but with only minor or no effects on non-trained motor tasks. Despite the important debate in the literature about the effectiveness of these exercises and the volume of training most commonly indicated for balance training in different groups, there seems to be a lack of dialogical and interdisciplinary debate about conceptual issues relating to the choice of terms used to refer to balance training. Many terms are used for the same type of exercise and there are considerable divergences about the relevance and accuracy of the terms.

The present study identified *balance training* as the most used and consistent term used in the literature, appearing in 471 of the 1105 articles selected. Additionally, researchers from Europe, followed by Asia and North America have published the highest number of studies on this topic, considering the criteria of our work. Publications have increased considerably in the recent years and the variety of terms used seems to be due to several conceptual and practical differences during postural balance training.

The combination of the terms *balance*, *sensorimotor*, *proprioceptive*, *functional* and *neuromuscular* with *training* was more frequently observed than with *exercise*. According the ACSM (2018), while *physical activity* is a term used to defined "any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase in caloric requirements over resting energy expenditure", *exercise* is a type of physical activity: "planned, structured, and repetitive bodily movement done to improve and/or maintain one or more [health-or skill-related] components of physical fitness" (ACSM, 2018 p 1–2). Milhem et al. (2014) define *training* as a planned process "to change attitudes, knowledge, skills



**Terms combinations: 30 papers use two main terms and two papers use three main terms**



**(b)**

**Fig. 1.** (a) Summary of the number of papers using the terms *balance training*; *balance exercise*; *sensorimotor training*; *sensorimotor exercise*; *neuromuscular training*; *neuromuscular exercise*; *proprioceptive training*; *proprioceptive exercise*; *functional training*; *functional exercise* in the title and/or keywords. If the sum of the parts of some expression exceeded the main term, the main term is associated with both (training and exercise) for some of the papers (For instance, Functional exercise (n = 93) + Functional training (n = 188) = 281; Functional = 278 and three papers used both terms (functional training and functional exercise)). (b) The number of papers that adopted more than one term and combinations.

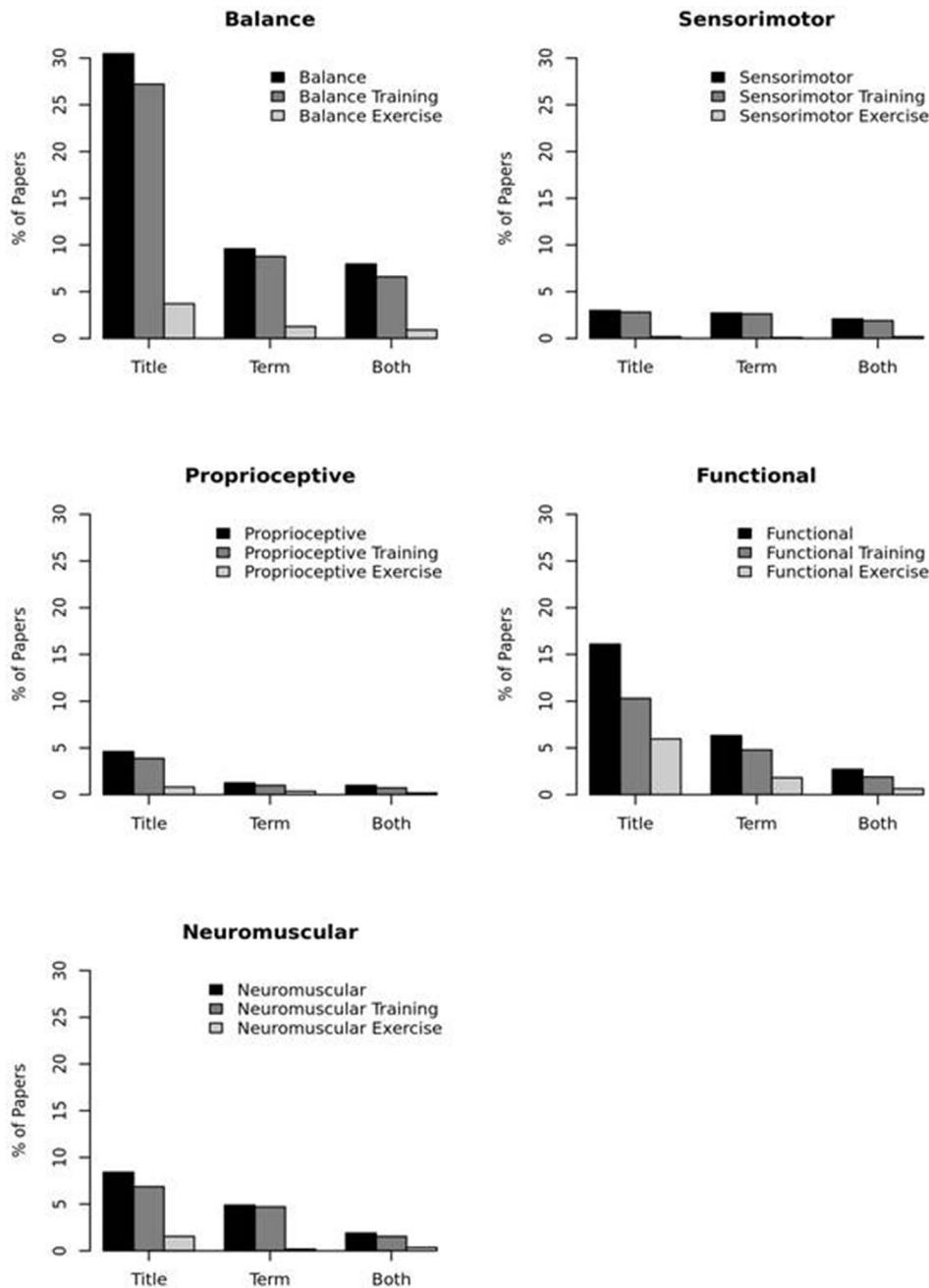


Fig. 2. Total number of studies according to the terms in the Title; Keywords or Both (title AND keywords).

and behavior” and to improve “performance in a specific activity or in a range of activities”.

Taube et al. (2008) had already reported that *balance training*, *proprioceptive training*, *sensorimotor training* and *neuromuscular training* were usual terms applied to address postural balance exercises aiming at postural control improvement. Our study also explored the terms *functional training* and *functional exercise*, as Ferreira et al. (2018) observed that these terms were also used to address balance exercises. These authors found that *balance training* and *proprioceptive training* are mainly used to address postural control exercises. However, there is a wide variety of exercises covered by the terms *sensorimotor training*, *neuromuscular training* and *functional training*. Thus, exercises using different physical attributes like strength, endurance and flexibility were

found. There were also postural control exercises, coordination and manual abilities to daily life exercise and aerobic exercises, among others (Ferreira et al., 2018).

#### 4.1. Conceptual analyses of the terms of interest

Page (2006) argued that the term *sensorimotor training* reinforces the inseparability of sensorial and motor systems in human movement control. The author uses *sensorimotor training* to address progressive exercises that challenge postural control and balance. However, Taube et al. (2008) suggested that this term refers to biological systems involved in any kind of physical exercise. These authors considered that any exercise or motor task requires afferent information from proprioceptors and depends on the sensorimotor

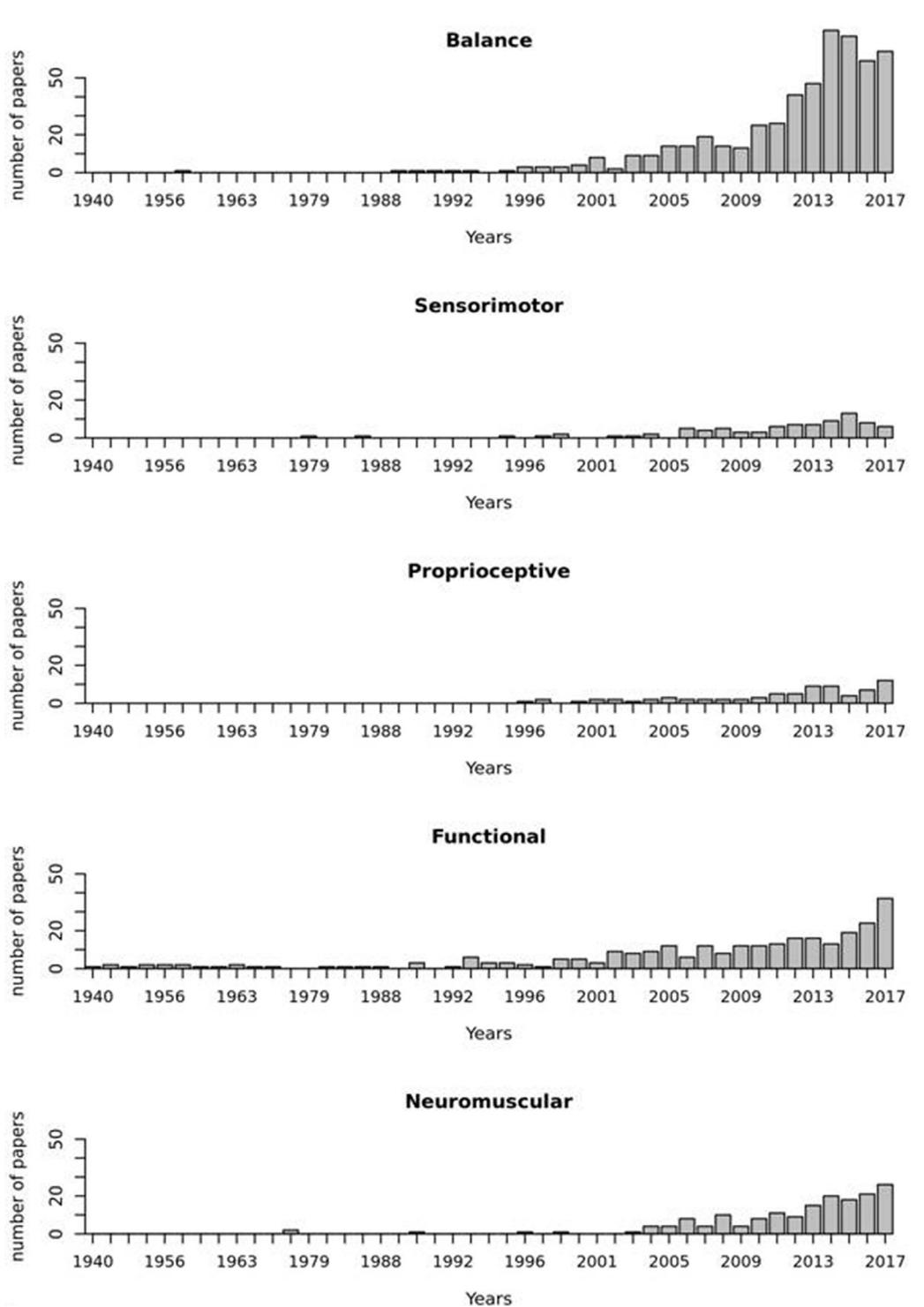


Fig. 3. Frequency of the terms: *Balance*, *Proprioceptive*, *Sensorimotor*, *Neuromuscular* and *Functional* (associated with exercise or training) over the years.

or neuromuscular interaction, because these parts are inherent in the musculoskeletal physiology. Considering that, [Taube et al. \(2008\)](#) pointed out that the nomenclature that addresses the motor skill (i.e. balance training) is the most suitable and the other terms do not properly delimit the balance skill.

On the other hand, considering activities based on interaction with other external forces, such as in bodybuilding exercises, it is essential to perceive, from moment to moment, the load (its weight

and shape) and the body segments' position and movements to constantly adapt and implement motor strategies. Thus, neuromuscular and sensorimotor adaptations also result in greater efficiency during these exercises. Therefore, neuromuscular and sensorimotor adaptations occur in different types of exercises and the gains are dependent on the exercise specificity. According to [Taube et al. \(2008\)](#), it is difficult to find an exercise modality that cannot be described by its neuromuscular/sensorimotor effects.

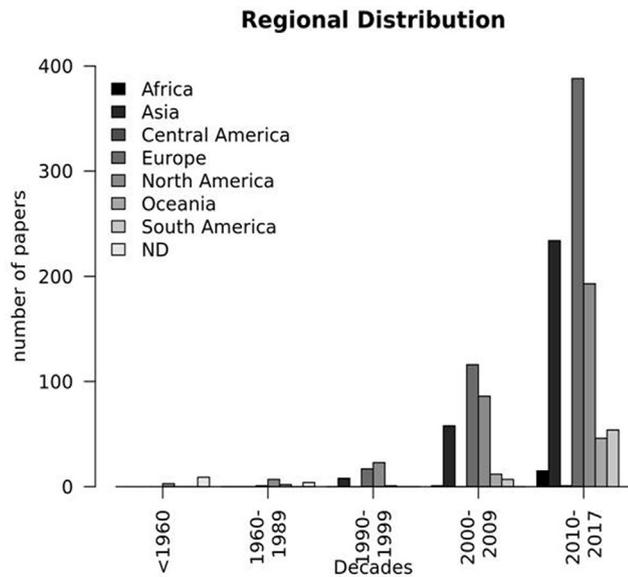


Fig. 4. Manuscript's geographical distribution over the decades, according to the author's continental affiliation.

These authors advocate that the term *balance training* is the most appropriate because it places the emphasis on the ability to be improved – namely, balance – without disregarding many biological structures and systems involved in the exercise, which can be improved by training, as the *proprioceptive training* term does. Taube et al. (2008) remind that the expression *proprioceptive training* is restricted to the afferent system, weighting the importance of all sensorimotor system, and disregarding the motor adaptations during training. In addition, Peterson (2017) quotes and recovers the proprioception as integrated into the neuromuscular system when he argues *functional training* concept.

Similarly, *functional training* should refer to the type of function to be trained, otherwise it can be a broader term and cannot delimit properly the exercise to which it refers. Thus, *functional training* may refer to daily living-like activities or in upper limb exercises to improve fine motor skills (Byl et al., 2008). The term is also used in rehabilitation, for instance, for exercises aimed at restoring temporomandibular function after mandible fracture (Feng et al., 2009). Conversely, according to Rogers's (2010) definition, functional exercise promotes “physical ability to perform daily living activities safely and independently without fatigue”. Peterson (2017) also states that *functional training* should be used to address a variety of exercises capable of improving activities of daily living. In this case, the activities are not a criterion that delimits *functional training*. Rogers (2010) argues that *functional training* became a hot term in the fitness industry. Siff (2002) has discussed the *functional training* concept within the sports, where there is confusion between sport-specific training and *functional training* when machines are not being used. Also, the author argues that multidimensional exercises as well as balance exercises on unstable surfaces have been defined as *functional training*. Siff (2002) did not restrict functional training to daily living activities.

Furthermore, the term *neuromuscular training* was reported with strengthening exercises when a vibrating weight was used (Tripp et al., 2009), but the Physical Activity Guidelines for Americans, released by the U.S. Department of Health and Human Services (2008), listed four components of *neuromuscular training*: muscle strengthening, body balance training, jumping, and learning the landing movements. In the guideline, *balance training* was considered part of *neuromuscular training*, which is, in

fact, a broader term. The authors registered a hierarchy between the two terms (i.e. *neuromuscular training* and *balance training*), often used improperly as synonyms in many cases. The Clinical Practice Guidelines (Logerstedt et al., 2010) used the terms neuromuscular and proprioceptive as synonyms when writing: “... neuromuscular (proprioceptive) training has been defined as movement training progressions that facilitate the development of [...]”. The Guideline on Previous Cruciate Ligament Injury (Meuffels et al., 2012) also collapse both terms when strongly recommend the “senso-motoric training (balance and proprioception) as part of a rehabilitation program [...]”.

The term proprioceptive training is often associated with the use of unstable surfaces (Ferreira et al., 2018). However, Ogard (2011) highlighted the lack of consensus in the use of the term and pointed out that the terminologies are often used improperly. Ogard (2011) considers a mistake to denominate balance exercises on unstable surfaces as proprioceptive exercises, considering that somatosensory system disturbance level on unstable surfaces requires, to a greater extent, visual and vestibular inputs for postural control, not directing the stimulus to the proprioceptive system. Thus, the author argues that more selective training is obtained with exercises on stable surfaces and that the visual suppression and unexpected disturbances strategies can be used to increase the challenge to the proprioceptive system.

Kim et al. (2011) suggested that proprioceptive training is a clinical concept to be used for rehabilitation exercises and only for leg exercises performed on stable surfaces. Cimino et al. (2010) used neuromuscular and proprioceptive training as equivalent terms that refer to the improvement of muscle reflex responses.

Beyond the disagreements about what terms should be used to refer to postural balance and the inconsistencies in arguments, antagonisms have also been presented – where the use of unstable surfaces, for example, justifies a term for one author and not using it for another. Another important issue is that terms such as *proprioception training*, *sensorimotor training*, *functional training* and *neuromuscular training* are used not only to refer to balance training but also to other concepts.

#### 4.2. Prevalence and adequacy of the terms for postural balance training

*Balance training* was the most prevalent term in the literature, which suggests some agreement between authors that this term is the most suitable to address exercise programs to improve postural balance control, because of the term is related to the competency to be achieved through training, instead of physiological systems or biological structures involved in all physical exercise. The ACSM also reinforces this approach when the ACSM Guideline (2018) structured physical fitness in health- and skill-related components, where balance is mentioned as a motor skill (ACSM, 2018).

Additionally, the use of the terms neuromuscular, sensorimotor and proprioceptive is growing in the last decades, mainly for the *neuromuscular* term. This increase suggests the need for a broader discussion about these terms and the appropriate use of them.

However, the use of the terms *functional training* or *functional exercise* to non-functional activities (i.e. those not used in daily living), as in the fitness industry, should be debated. Is it a marketing strategy or is it based on a scientific basis?

#### 4.3. Study limitations

Some limitations must be taken into account while analyzing the results of this study. First, results of the present study must be interpreted with caution, given the literature search excluded original articles that did not use the terms of interest in the title or

keywords. Thus, relevant papers on this topic that did not comply with the inclusion criteria were not considered in the results. Further, the analysis only has considered papers in English that used the terms selected in the title and keywords, disregarding publications in other languages – which would potentially increase the continents' contribution. In addition, it was not our goal to analyze the research area of the authors, which could explain trends in the use of particular terms depending on the field of study. Another important limitation is that only one database (i.e. Scopus) was considered. Finally, the present study did not aim to analyze the methodological quality of the articles, since it was not intended to prove the effectiveness or efficiency of training protocols, but only to observe the frequency of use of certain terms in the literature.

In summary, the frequency of terms used to address postural balance training was searched. The most consistent and used term was *balance training*. It was observed an increase in the number of studies using the various terms over the years, mainly in the 21st century. However, there are differences in the description of the characteristics related to each term and important conceptual differences, indicating the need for a broad debate to conceptualize, characterize and standardize the use of those terms to address physical exercises for rehabilitation or sports.

## 5. Clinical relevance

- Balance training seems to be the most suitable term to refer to postural control.
- The variety of terms seems to be due to several conceptual and practical differences to postural balance training. It is important to (re)start the debate about nomenclature and concepts.
- These results contribute to stimulate the necessary conceptual debate, considering physiological, clinical and training approaches in order to improve the communication in the sport and in the clinical environment.

## Declaration of competing interest

None.

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