REVIEW ARTICLE

FALL IN OLDER ADULTS: CONSIDERATIONS ON BALANCE REGULATION, POSTURAL STRATEGIES, AND PHYSICAL EXERCISE

Queda em adultos idosos: considerações sobre a regulação do equilíbrio, estratégias posturais e exercício físico

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ABSTRACT

Common among the older population, falls are considered a public health issue, accounting for high rates of morbidity and mortality. Thus, there is a need for theoretical studies that improve the understanding of the relationship between falls and their risk factors; the pathophysiology of balance and gait disorders; and early identification of "idiopathic fall" (with no apparent cause). Based on the specialized literature, the present study provides an overview of the role of sensory systems responsible for regulating postural control, showing the main strategies that older adults use to maintain postural control and the benefits of regular physical exercise for prevention of falls in older adults. Then, a graphic model describing the sequence of strategies used by older adults to regain an upright stance in different phases of postural perturbation is presented. In conclusion, poor performance of attention, memory, and executive functions increases postural instability and reduces gait speed, thereby raising the risk of falls. In this context, regular physical exercise may significantly reduce the rate of falls in older adults. Planned exercises are recommended and should involve cognitive tasks with moderate-to-high level of instability for two to three hours/week.
KEYWORDS: accidental falls; postural balance; cognition; aging.

RESUMO

Quedas são comuns entre a população idosa, consideradas como questão de saúde pública, responsáveis por alto grau de morbidade e mortalidade. Isso evidencia a realização de estudos teóricos que qualifiquem o entendimento sobre a relação entre queda e seus fatores de risco; a fisiopatologia dos distúrbios do equilíbrio e da marcha; e a identificação precoce da "queda idiopática" (sem causa evidente). Assim, com base na literatura especializada, o presente estudo apresenta uma visão geral sobre o papel dos sistemas sensoriais responsáveis pela regulação do controle postural, evidenciando as principais estratégias utilizadas por idosos para a manutenção do controle postural e os benefícios proporcionados pela prática regular do exercício físico para a prevenção de quedas de idosos. Como resultado, é apresentado um modelo ilustrativo sobre a sequência de estratégias utilizadas por idosos para reestabelecer a posição ereta em diferentes fases de perturbação postural. Conclui-se que o baixo desempenho da atenção, da memória e de funções executivas eleva a instabilidade postural e reduz a velocidade da marcha, aumentando o risco de quedas. Nesse contexto, a prática regular de exercícios físicos é capaz de reduzir significativamente a taxa de queda de idosos. Aconselham-se a prática de exercícios programados, que agreguem tarefas cognitivas com grau de desafio da instabilidade de moderado a alto, e a prática semanal de duas a três horas.
PALAVRAS-CHAVE: acidentes por quedas; equilíbrio postural; cognição; envelhecimento.

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INTRODUCTION

In recent decades, a great number of investigations have addressed the topic of falls in older adults. A PubMed search using the terms "fall elderly" or "falls risk" for the period of 2008 to 2018 yielded 15.442 and 12.050 articles, respectively. Furthermore, in the same period there were 8.616 published studies on "falls prevention". These results show the concern of different health care fields for the issue of falls in older adults.

According to specialized literature estimates, approximately 30% of the older population falls once a year,[1,2] with greater risk for older women.[3] In view of that number, the World Health Organization[4] addresses the situation as a public health issue because falls lead to injuries and fractures. Therefore, falls significantly affect a person's autonomy, reducing the perceived quality of life.[5] Another issue associated with falls in older adults involves the combination of hospitalizations and resulting costs. In a study based on the Brazilian Ministry of Health database, Barros et al.[6] identified 399.681 admissions of older adults in the period of 2005 to 2010, generating a cost of approximately USD 127 million for hospital admission authorization services.

The specialized literature indicates that falls are caused by a range of factors classified as extrinsic and intrinsic.[7,8] Extrinsic factors are related to infrastructure features of the environment, including circumstantial aspects of flooring and lighting, which may become a danger to people's safety. Intrinsic factors, in turn, are associated with physiological changes affecting the human body as a result of the aging process.[9] Thus, based on the facts, early identification of risks of fall is important in older adults. Conversely, this is a complex task, as a fall involves multiple factors.[2]

For that reason, the association of different instruments and/or scales is recommended.[7,8] The same applies to procedures of fall prevention, which requires the use of distinct methods. Among these are educational activities with a focus on raising awareness of older adults about potential dangers (extrinsic factors), which may favor changes in living habits, including becoming more cautious. A second strategy consists of encouraging older adults to practice physical exercises, which improves their levels of physical fitness.[8]

As the person ages, the body undergoes a series of neurodegenerative changes that will significantly impair the efficiency of neuromuscular control and the systems responsible for postural adjustments in situations of imbalance.[10] For that reason, older individuals are more susceptible to falls than healthy young adults.[11] The main changes leading to increased risk of falls include the following: altered sensory and motor systems;[12] impaired static and dynamic balance;[8] decreased muscle strength and power in the lower limbs;[3] altered gait pattern;[10] low levels of flexibility;[10,12] impaired cognitive status;[13] decreased visual acuity;[14,15] and fear of falling.[16]

In this context, exercising properly and regularly is known to maintain or even improve the physical and cognitive status of older individuals, protecting them from falling.[17,18] Systematic reviews with meta-analysis have shown that physical exercise is an effective and low-cost mechanism to prevent falls.[16,17] According to the authors, the findings may be generalized to most older adults. Moreover, physical exercise is well accepted by this population and adds the benefit of increased social contact, which produces stronger bonds.

However, in a study titled "The neurobiology of falls," Fasano et al.[19] suggest that fall approach should not focus solely on the disease. To the authors, the situation also requires a prior understanding of the pathophysiological process leading to falls. Even if the chance of falling of a healthy individual aged 65 years or above with no history of falls is 27%, the single predictor for future falls is known to be the individual's history of previous fall. However, the evidence is insufficient for the recommendation of any primary prevention intervention.[19] This shows the importance of conducting studies that allow the identification of individuals classified as "idiopathic fallers," *i.e.*, those who fall even when there is no apparent reason or underlying illness.[19]

The present study aimed, based on the specialized literature, to introduce theoretical aspects of the role of sensory systems responsible for regulating postural control; to describe different strategies used by older adults to maintain their balance; as well as to show the importance of regular physical exercise in preventing falls in the older population.

METHOD

This integrative literature review focuses on falls in older adults, including three topics: sensory systems responsible for regulating body balance; strategies adopted by older adults to prevent falls; and benefits of structured physical exercise for reducing the risk of falls. SciELO, MEDLINE, LILACS, and Google Scholar databases were searched using the following descriptors: fall elderly, fall risk, and falls prevention. The following inclusion criteria were used:

- published studies written in Portuguese or English;
- age of the population ≥ 60 years.

FALL AND POSTURAL CONTROL

A fall event is defined as a change in the position of the individual to a lower level compared to the current position, followed by unintentional contact with the support surface, not requiring an intrinsic factor or unavoidable accident.[20] One of the most complex intrinsic factors leading to falls is postural control (balance), which may, however, be treated through physical exercise.[5,12-16] Impaired motor skills significantly increase the risk of falls,[1,2] especially in the older population.[5,6]

The regulation of postural control is a triple input system with a single output.[12] Initially, somatosensory, visual, and vestibular systems capture postural data regarding positions of the body and its extremities in space; then these data are processed in the central nervous system (CNS).[15] Thus, the CNS is responsible for integrating postural inputs, which are transformed into important information. Based on this information, the CNS sends a series of postural adjustments to body extremities, which is essential to maintain the center of gravity over the base of support of the body.[21]

It is worth noting that the processes used to integrate postural data are carried out in the brain, cerebellum, basal ganglia, and brainstem.[9] The latter consists of ascending and descending pathways from where commands are sent to tone regulation (postural command), which is then executed through motor reflexes. If balance regulation systems (proprioception, vision, hearing) are partially or totally impaired, the CNS is prevented from tracing corrective strategies in time. This means that impaired sensory regulation systems may hinder postural adjustments, considerably increasing the risk of falls.[9-11]

Systematic reviews[22] and meta-analysis[7] have described that sustaining static and dynamic balance is a complex process, because it requires effectiveness from the three sensory systems as well as proper functioning of the motor system and cognitive processing speed (executive functions).[13,19] Additionally, maintaining an upright posture is also influenced by body morphology, including variables such as height, foot length, and weight distribution.[9]

BALANCE REGULATION AND POSTURAL STRATEGIES

Overall, four strategies are applied to the maintenance of body balance: ankle, hip, gait, and arms. Figure 1 sequentially illustrates four strategies that individuals use to avoid imbalance and falls.

The situations shown in Figure 1 require the CNS to perform adaptive measures to select the most appropriate strategy of postural stabilization in four scenarios: normality, perturbation, near-fall, and fall. The resources employed for postural adjustment are described below:

- Phase 1a (ankle strategy): when late detecting a mild threat of unbalance, the CNS immediately recruits, via internal and external somatosensory input, ankle muscles to correct and/or maintain postural control.[19] There is then slight release (relaxation) of the trunk muscles and consequent stiffening of the ankle joint.[23] This postural strategy is considered a subconscious reflex. It is worth noting that, because of increased age, older adults gradually lose strength in ankle stabilizer muscles, which forces the body to automatically execute the next strategy;
- Phase 1b (hip strategy): if greater forces act on the body, threatening a stable upright posture, the CNS initiates the hip strategy.[19] This mechanism involves late activation of trunk and thigh muscles, radiating forces in the proximal-distal direction.[13] Comparatively, the hip strategy demands the activation of ankle plantar flexors, knee flexors, and hip extensors, while the hip strategy requires the activation of knee extensors and hip flexors. According to Blenkinsop et al.,[23] the ankle strategy is generally used in situations of unperturbed posture and slow or low amplitude perturbations. Conversely, the hip strategy is employed in circumstances of fast or large amplitude perturbations. An example is when an individual is standing on a narrow support surface, which hampers the use of ankle torque;
- Phase 2 (stepping strategy): when high-intensity episodes occur and previous mechanisms have failed to restore balance, unbalance is detected, and the CNS automatically discontinues the ankle and hip strategies and activates the stepping strategy.[19] Messages are sent to the extremities, while in parallel the CNS requires the base of support to be repositioned; then the individual takes a step forward, or backward, or to the side.[13] During the process, the ankle joint is released, allowing an enlargement of the base of support of the body;
- Phase 3 (near-fall): if previous motor acts have failed to preserve postural stability, the CNS mobilizes the upper limbs as a posture rescue strategy. The action is reflexive and primarily seeks to avoid and/or minimize the impending accident.[13,19] From a kinematic

perspective, in near-fall situations, regardless of the strategy employed by the CNS, both the body movement and the ankle and/or hip torque are inevitable.[23] In this context, accelerations of one segment will result in accelerations of other segments, which must be controlled by the appropriate muscles.[24] Meanwhile, the CNS sends stimuli resulting in compensatory hip torque acting in the same direction as ankle torque, accelerating leg movement. The hip strategy also generates complementary ankle torque acting in the opposite direction to hip torque, producing rotation of the upper and lower limbs.[23]

Overall, the sequence of strategies outlined in Figure 1 is a response to inadequate flow of postural information from visual, vestibular, and somatosensory afferents.[9,13] Thus, the chain of actions employed consists of a response to sensory and executive dysfunctions that the body uses to adapt to the circumstances leading to a fall. This can be defined as the inability of the body

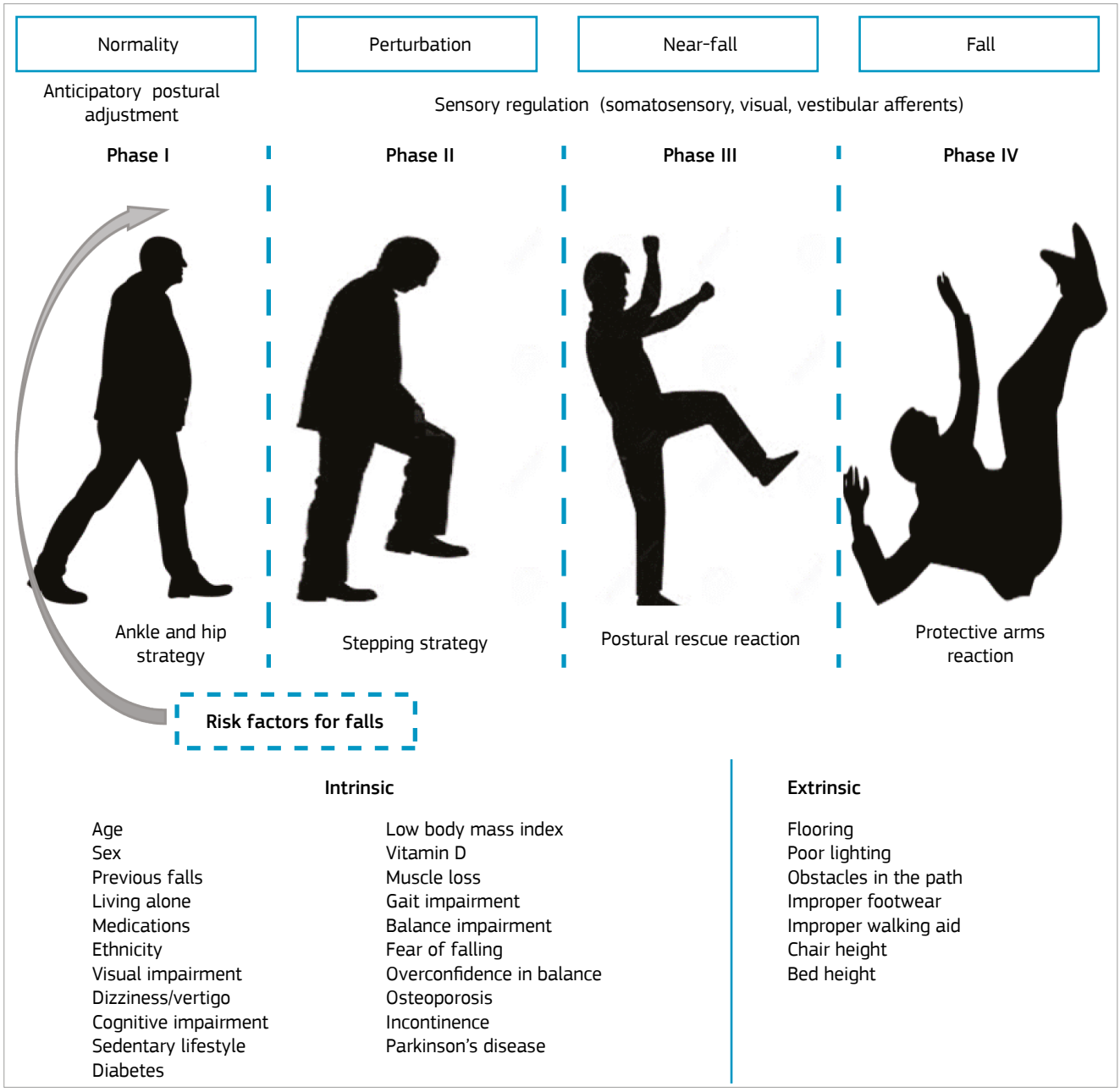

Figure 1 Model showing the sequence of strategies used for preservation of body stability after a perturbation. Schematic representation based on the studies of Montero-Odasso & Speechley[13] and Fasano et al.[19]

(sensory system of body balance) to react in time against external perturbations.[14,15]

The specialized literature suggests that, in addition to neural impairment responsible for balance regulation, fear of falling significantly potentiates the risk of falls in older adults. Fear of falling is estimated to increase the risk of fall by 25%, especially among recurrent fallers.[16,25] Young & Williams[26] reported that fear of falling generates anxiety, thus decreasing the attentional processes required to maintain balance as well as affecting gait speed. These factors considerably compromise the planning of safe actions during complex locomotor tasks.

Fasano et al.[19] described that, although gait and postural stability are automatic (subcortical) processes, the range of strategies used to manage postural perturbations is closely associated with cortical functions. Thus, in addition to an adequate flow of information obtained through sensory inputs from somatosensory, visual, and vestibular afferents, maintaining an upright stance requires cognitive resources.

A systematic review conducted by Kearney et al.[27] found that, in community-dwelling older adults, falls were associated with low gait speed and impaired executive functions (Figure 1). According to the authors, executive functions are responsible for inhibitory control, attention, working memory, and cognitive flexibility. They play a relevant role in the processing of postural information; thus, cognitive impairment slows down human mobility.[23-25]

It is worth noting that even older adults with normal cognitive performance may present with executive dysfunctions. This line of reasoning shows the importance of early identification of "idiopathic faller" older adults. For this reason, clinical practice uses a set of specific instruments for examining impaired executive functions:[28] Verbal Fluency Test, Trail Making Test (TMT), Montreal Cognitive Assessment (MoCA), Clock Drawing Test (CDT), or Mini Mental State Examination (MMSE).

CONTRIBUTIONS OF PHYSICAL EXERCISE TO FALL PREVENTION

According to the American College of Sports Medicine,[29] exercise is a planned, structured, and repetitive body movement whose purpose is to improve or maintain one or more components of physical fitness. Systematic reviews with meta-analysis[30,31] have shown that physical exercise, when performed in a regular and planned manner, may significantly reduce the rate of falls in the older population. Its effects maintain and/or improve the performance of the physiological system, with a positive impact on mobility and functional capacity, thus enabling the resolution of ADLs. Additionally, physical exercise is well accepted by older adults.[32]

A recent systematic review[33] demonstrated that exercises involving dance, exergaming, and ball sports may delay cognitive decline. This occurs because those activities are beneficial to brain areas responsible for multiple domains, contributing to balance rescue during gait (Figure 1). In another systematic review with meta-analysis consisting of 88 trials (19.478 individuals), Sherrington et al.[17] showed that physical activity reduced by 21% the rate of falls in older adults. According to the authors, the greatest effect on falls was observed in exercise programs that challenged balance and consisted of ≥ 3 hours/week. Moreover, regular exercise had a preventive effect on falls among older adults with Parkinson's disease or cognitive impairment.

There is no consensus in the specialized literature on the best type of exercise to prevent falls in older adults.[25] However, exercise is known to have advantages when performed in a structured manner.[34,35] The benefits result from planning, frequency, and progression of physical activities. In the international literature, Otago[36] has been reported as an exercise program capable of reducing the rate of falls by 35%. The advantages of this program, especially for individuals with restrictions to move to the place where group activities are offered, include the possibility of performing exercises at the older adult's home. The program also provides five home visits by physical therapy or nursing professionals. They are in charge of teaching and overseeing the activities, which are then followed by monthly phone follow-up.

BALANCE

Lahr et al.[21] observed some level of postural sway in the base of support of both older individuals (75,4 ± 5,7 years) and young adults (22,6 ± 2,33 years). The authors reported, however, greater sway among older adults. Furthermore, older adults showed limited functioning of the three sensory systems, which impaired their performance in the tasks as the difficulty level increased (standing on a force plate for 30 seconds in normal and semi-tandem stances).

A meta-analysis conducted by Sherrington et al.[37] reported that planned exercise programs reduced the rate of falls by up to 42%. According to the authors, the most effective physical activities were those with moderate-to-high level of challenge, practiced for at least 2 hours/week, for 6 months. They also recommended the association of strength and walking

training with educational measures, which they see as key to changing living habits.

Based on the 57 studies analyzed by Sherrington et al.,[37] the following activities were recommended for fall prevention training:

- reducing the base of support: standing with both legs close together, standing with one foot directly in front of the other (tandem stance) and, if possible, standing on one leg;
- movements that disturb the center of gravity: tandem walking, transferring body weight from one leg to the other, overcoming obstacles, stepping up onto stable objects;
- specific resistance training for postural muscles: squat, hip abduction (with additional weights);
- reducing the sensory input: exercising with eyes closed, walking forward and backwards on unstable and/or reduced surfaces;
- increasing the challenges through dual-task activities: associating tasks of memory, attention, and calculation with tasks of gait, coordination, and static and dynamic balance.

Ghai et al.[22] screened 1.284 studies and selected 42 (1.480 participants) for review. Of the studies investigating the effects of dual-task training on postural stability, 87,5% reported significant improvements, while 30% of the studies evaluating acute effects of dual tasks on posture reported significant improvements. The findings were confirmed through a meta-analysis that showed moderate but significant effects (95% confidence interval, 1,16–2,10) for reduced risk of falls in community-dwelling older adults.

STRENGTH

One of the negative effects of the aging process on the human body is sarcopenia. This physiological change is caused by oxidative stress, which reduces the production of testosterone in the body.[38] Then, the natural production of anabolic substances decreases, as well as their effects on skeletal muscle tissue. This leads to an accelerated process of tissue atrophy and reduced muscle strength. All these factors potentiate the loss of muscle mass. However, strength training may provide the older adult's body with the necessary means to mitigate this physiological process.

As exercise overloads the muscles, there is increased speed of muscle contraction. The individual is then able to react quickly in situations of imbalance (Figure 1). Postural control consists of an integrated system that improves the speed of muscle contraction, while the CNS is able to expedite corrective information, which is more safely sent to body extremities. Previous studies[18,39] of older adults have shown that resistance training, consisting of 3 to 4 sets of 12 to 15 repetitions and adjustment of loads when reported as being light, provided significant strength increase. Additionally, a significant improvement was observed in the results of gait and functional balance tests.

Conversely, Orsano et al.[40] reported that power training is more effective than traditional slow or moderate strength training in the older population. In power training, the concentric phase is performed faster, which leads to the activation of a larger number of motor units and, therefore, better adaptation of type II fibers. According to the authors, this technique can be practiced in weight machines or using free weights and elastic bands; the concentric phase should be performed in < 1 second, whereas the eccentric phase in approximately 2 to 3 seconds.

MOBILITY

As age advances, there are also changes in gait pattern. Systematic reviews have reported low speed and increased stride variability (stride time, step length, and double-limb support time) in older adults, especially in situations requiring divided attention.[41,42] Conversely, dual-task training may reverse the scenario, improving both gait speed and stride length and variability.[22,43]

In a cross-sectional study of healthy women aged 65 to 75 years, Ciprandi et al.[44] found a significant and negative association between gait variability and physical activity. Thus, increased levels of physical fitness may minimize the risk of falls in older adults. In an observational study of 103 older individuals (aged 76,3 ± 7,2 years), including 56% of women with gait disorders and memory impairment, Auvinet et al.[45] reported postural instability in a gait analysis under dual-task conditions. The authors also associated postural imbalance with four pathological subgroups, *i.e.*, musculoskeletal diseases, vestibular diseases, mild cognitive impairment, and CNS pathologies.

CONCLUSION

The findings reported in the present study lead to the conclusion that clinical professionals committed to fall

prevention in older adults should extend their knowledge on the intersection between risk of falls and associated factors, as well as on pathophysiology of falls.[10,13] Based on the information presented, special attention should be provided to older individuals with cognitive impairment. Regarding regular exercise, there is a need for favoring properly planned and structured activities,[30,35] including methods that involve cognitive tasks.[22,28]

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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