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Senescence – a determinant or contributory cause of increasing the risk of falling? (Note II)
Senescenţa - factor determinant sau cauză favorizantă pentru creşterea riscului de cădere? (Nota II)

Dana-Maria Dimulescu, Gheorghe Chiriţi
"Carol Davila" University of Medicine and Pharmacy, Bucharest
National Institute of Rehabilitation, Physical Medicine and Balneoclimatology

Abstract

Age-related changes in gait are defined by: reduced peak hip extension, increased anterior pelvic tilt, an increase in peak external hip flexion moment in stance, a reduction in knee flexion moment in preswing, reduction in knee power absorption in preswing, reduced ankle plantar flexion and ankle power generation.

Older persons with a high risk of falls had significantly longer response and transfer times than the young group. Errors in stepping, performing the secondary task and contacting the obstacle were increased with age and fall risk. The fall-prevention programs were effective by reducing fall rates by 14%, in multifactorial interventions. The interventions aimed at increasing safety at home are efficient in reducing the rate of falls and the risk of falling.

Key words: senescence, fall risk, gait abnormalities.

Rezumat

Modificările date de vârstă se definesc, în privinţa mersului, prin: creşterea înclinării anterioare a pelvisului, scăderea peak-ului extensiei şoldului, creşterea peak-ului extern al flexiei şoldului, reducerea flexiei genunchiului, scăderea puterii de absorbţie a genunchiului în prebalans, scăderea flexiei plantare a gleznei şi a forţei generate de gleznă.

Vârstnicii cu risc crescut de cădere prezintă un răspuns semnificativ mai lung şi un timp de transfer mai mare decât al tinerilor. Erorile în derularea paşilor, performarea sarcinilor secundare şi contactul cu obstacolele au crescut cu vârsta şi riscul de cădere. Programele de prevenire a căderilor au fost eficiente, prin scăderea căderilor cu 14%, în intervenţiile multifactoriale. Intervenţiile de creştere a siguranţei la domiciliu sunt eficiente în reducerea ratei şi a riscului de cădere.

Cuvinte-cheie: senescenţa, risc de cădere, tulburări de mers.

Kinematics of the pelvis and legs in elderly and young adults. Kinetic changes unrelated to the walking speed

The decrease of hip extension and the increase in the forward pelvic tilt among the elderly population are both specific to dynamic walking and they do not occur while standing. Comparative surveys were conducted on elderly people with an average age of 71 years and on young adults with an average age of 26 years. They were studied while standing and walking comfortably, at low and high speed.

The kinematics of the pelvis and legs was measured using a three-dimensional movement-analysing video system. The peak of the hip extension and the forward pelvic tilt were thus determined; while standing, there were no significant statistical differences between the elderly and the younger subjects, with respect to the hip extension and the forward pelvic tilt.

At a comfortable walking speed, the elderly group had a decrease in the hip extension peak and a higher forward pelvic tilt compared to the young adult group. At a fast walking speed, the extension peak was significantly lower within the elderly group compared to the young adult group. However, there were no significant differences in this respect during slow speed walking. Age-related changes are defined, in terms of walking, by reduced hip extension and increased pelvic tilt, which is rather a dynamic phenomenon than a phenomenon incurred while standing (Lee et al., 2005).

The decrease of hip extension among the elderly becomes even more visible in frequent fallers. The use of a three-dimensional system to conduct an optoelectronic analysis of movement allowed the performance of a comparison between the entire kinematic walking chain, from a sagittal point of view (from the viewpoint of movements made at leg joint level and at pelvic level), in

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Address for correspondence: "Carol Davila" University of Medicine and Pharmacy, Bucharest, Faculty of Medicine, Eroilor Sanitari Av. no.8
E-mail: dm.dimulescu@gmail.com
Correspoding author: Dana-Maria Dimulescu

elderly people and in young adults, as well as a comparison of the same between elderly people who suffered frequent falls and those who did not fall at all. The comparison was made on each elderly group, during comfortable and fast walking. It was performed in a walking laboratory, on 23 healthy elderly people, 16 elderly people known to be fallers or healthy old people having a history of recurrent falls, and 30 young adults. The following were assessed: the pelvic position and the peak of joint angles; the hip extension peak was the only parameter of the leg joint, measured during walking, which proved to be significantly lower in the elderly group (both fallers and non-fallers) compared to the group of young adults. This parameter evidenced equal regressions in the group of elderly people who had frequent falls, and those who were not known to be fallers ($p \leq 0.05$). The hip extension peak +/- the standard deviation during comfortable walking was around 20.4º+/- 4º for the young adults, 14.3º+/- 4.4º for the group of elderly people without falls and 11.1º+/- 4.8º for the group of elderly people who had frequent falls. The hip extension peak showed no significant improvement among the elderly, during fast speed walking (Kerrigan et al., 2001). The reduced walking hip extension among the elderly, which was exaggerated among old people with frequent falls, impaired the walking performance and the general functionality of the hip.

Surveys were conducted on the kinetic alterations occurring among the elderly, unrelated to the walking speed. Among the elderly people who had frequent falls, these kinetic alterations were comparable, for the comfortable walking speed, to those recorded among the elderly with no falls, at fast walking speed. This was proven through retrospective studies, by the use of the strength platform in elderly people who, for unknown reasons, had at least 2 falls during the last 6 months and in elderly people with no history of recurrent falls.

The differences in the peak of joint kinetics (moment and power) were assessed during the gait cycle, and they were compared in elderly with a history of recurrent falls, during comfortable and fast speed walking.

The significant differences were analysed for 4 sagittal plane parameters, both for comfortable and for fast walking speed: an increase in peak external hip flexion moment in stance, a reduction in peak hip extension moment, a reduction in knee flexion moment in preswing and a reduction in knee power absorption in preswing. The presence and the persistence of the 4 kinetic alterations, both at comfortable and at high speed, implies the existence of different inherent specific patterns and allows for new approaches in analysing the walking mechanism of elderly people who have frequent falls. These joint kinetic alterations could serve as potential markers for detecting the risk of falling among the elderly (Kerrigan et al., 2000).

Some surveys tried to identify biomechanical gait alterations unrelated to the walking speed among healthy elderly people, and for this purpose, they analysed the decrease in power and in gait performance. Thus, they identified the age-driven changes in the biomechanics of gait and attempted to determine whether these changes were still present when the walking speed increased.

The different values in the peak of various joint movements (from a kinematic point of view), as well as the joint momentum and strength (from a kinetic point of view) were determined, and these values were compared for the healthy elderly group and for the young adult group at comfortable and at high walking speed. The survey was conducted on 31 healthy old persons (between 60 and 84 years old) and on 31 healthy young adults (between 18 and 36 years old), without any known neurological, musculoskeletal, cardiac or pulmonary disorders. During the gait cycle, the major kinematic and kinetic peaks were assessed. Several kinetic and kinematic differences were detected between the elderly and the young adults, but they did not persist once the walking speed was increased. The differences that did persist, even after moving from comfortable to fast walking, were: decrease in the hip extension peak, increase in the anterior pelvic tilt, decrease of the ankle plantar flexion, reduction of the ankle power generation. Gait performance can be impaired in elderly people through two factors: hip flexion contracture and ankle plantarflexor concentric weakness (Kerrigan et al., 1998).

The gait pattern of 8 elderly people (66.8+/-5.4 years) and 12 young adults (26.6+/-2.8 years) was recorded for normal walking speed (1.0 m/s, 1.3 m/s, 1.6 m/s). There was no difference in speed between the groups. Combining speeds among the healthy elderly group led to a 17% drop in the ankle generated force and a 12% drop in the mechanical work generated by the joint ($p \leq 0.05$). In elderly people, these changes were associated with a reduced plantar ankle flexion, as well as an increase in the hip flexion and in the anterior pelvic tilt ($p \leq 0.05$). The elderly take various walking patterns; at rapid walking speed, the hip flexion propels the leg during balance, when the ankle plantar flexion is low (Cofre et al., 2011).

Efficiency of fall-prevention programmes among the elderly. Influencing the falling rate and the falling risk among the elderly

Some surveys were conducted on the efficiency of fall-prevention programmes among the elderly, by reviewing randomized controlled trials, between 2000 and 2009. The parameters measured were the number of falls and the falling rate. The fall prevention programmes implemented so far were quite efficient, as they reduced the number of falls by 14%, through multi-factor interventions. There were no variations between multi-factor interventions and single-factor interventions. Among the elderly living in the community, who received assistance at home, the falling rate dropped by 9% (Choi, 2012).

The fall-risk reduction interventions were assessed among people aged over 65, through 159 trials, attended by 79193 participants. The prevention intervention was compared to the situation when no measures were taken.

In the multiple component exercise groups, the falling rate and the falling risk dropped significantly. The application of the Tai Chi type programme led to a significant drop in the falling risk. The multi-factor intervention that included the assessment of individual risk led to an important drop in the falling rate, without, however, influencing the risk of falling.

Additional vitamin D intake influenced neither the falling risk nor the falling rate. The interventions aimed at increasing safety at home were efficient in reducing both the falling risk and the falling rate. These interventions proved to be more efficient in the case of elderly people with a high risk of falling, including those with severe sight impairment. These interventions meant to increase safety at home were specific to occupational therapy. A sight issues analysis among the elderly revealed a significant increase in both the rate and the risk of falling. Correcting these sight issues through the use of multi-focal lenses led to a significant drop in the falling risk among the subgroup of elderly people involved in outside activities. Pacemakers reduced the falling rate among those suffering from carotid sinus hypersensitivity, influencing the risk of falling. The first eye surgery conducted on a woman suffering from web eye reduced the falling rate, while the second surgery, conducted on the other eye, had no effect at all. The gradual withdrawal of psychotropic substances reduced the falling rate but not the risk of falling. Prescribing a modified programme for primary physical care decreased the risk of falling. Wearing non-slippery shoes reduced the risk of falling on ice (Gillespie et al., 2012).

The permanent slippery properties of shoes on ice – the friction coefficient computed for 4 different materials (synthetic rubber, nitrile, natural and polyurethane) were measured on ice (at a temperature of -12 degrees); the rigidity and roughness of the shoes were also measured.

According to the results, polyurethane did not perform better than synthetic rubber, nitrile, or natural on pure ice (-12 degree). A rough sole was positively associated with the friction coefficient; the best slipping material on the floor (polyurethane) did not offer enough slipping capacity on ice (Gao et al., 2004).

By comparing the ankle-foot complex among impaired elderly and those suffering from pain in that area through multi-faced and standard stepping measurement, it has been established that after an exercising programme, the falling rate drops but the risk of falling does not.

The effect of cognitive behaviour also bears an influence on the falling rate, while it has no influence at all on the risk of falling. Several interventions were initiated in order to increase the knowledge/education level among the elderly, for fall prevention purposes. These trials comprised interventions concerning the exercises performed at home by those aged over 80, they assessed home safety and the changes made prior to the fall occurrence, including a multi-functional programme focusing on specific risk factors. The home exercising programmes aimed at increasing safety at home (through adaptation) led to a drop in the fall rate and in the risk of falling. The multi-factor assessment and the interventions made through prevention programmes reduced the falling rate but they did not influence the risk of falling.

The risk factors encountered at home are associated with the decay of physical abilities and the exposure to surrounding stress elements, thus leading to an increased risk of accidental falling, especially outside the home. There is no linear relation between mobility and accidental falls; a good mobility makes, however, elderly people more likely to resist falls. A decrease in the falling incidents occurring at home is included in the fall prevention strategy and the strategy to reduce the risk of falling among the elderly, focusing on mobility-impaired elderly people with a history of falling (Lord et al., 2006).

Home safety guide

Issues:

1) The floor

- Potential risk of falling: polished or wet surfaces that facilitate slipping
- Adapting recommendations: non-slippery sandstone in the bathroom, non-slippery carpets in the bathroom, toilet, kitchen.

2) Rugs

- Potential risk of falling: elderly people can trip on thick rugs
- Adapting recommendations: thin rugs, without thick edges

3) Carpets

- Potential risk of falling: they can be slippery
- Adapting recommendations: non-slippery carpets

4) Light

- Potential risk of falling – low light – risky
- Adapting recommendations: strong lights in high risk places – stairs, bathroom, bedroom

5) Glow

- Potential risk of falling – things that glow in the sun
- Adapting recommendations: polarized glass windows or curtains, careful positioning of the lamps

6) Stairs

- Potential risk of falling – low light – risky
- Adapting recommendations: switchers on both ends of the stairs, non-stop night lamps, duct tape on the stairs. The stairs must not be higher than 14 cm.

7) Rails

- Potential risk of falling – no rails – risky
- Adapting recommendations: place rails on both sides of the stairs

8) Sink and towel stand

- Potential risk of falling – slippery – risky
- Adapting recommendations: to be placed at an adequate height and location.

9) Toilet set

- Potential risk of falling – low chair – risky
- Adapting recommendations: higher toilet chair.

10) Bath or shower tub

- Potential risk of falling – slippery – risky
- Adapting recommendations: non-slippery surface and support rails on the walls, flexible shower, possibly equipped with a chair.

11) Bed

- Adapting recommendations: adequate height for an optimal transfer.

12) Mattress

- Adapting recommendations: well balanced and fixed

13) Chairs

- Adapting recommendations: adequate height with arms support

14) Shelves

- Adapting recommendations: adequate height in the kitchen and bathroom

15) Gas

- Potential falling risk: asphyxiation risk

- Adapting recommendations: marking the open/close position in an obvious, clear manner.

16) Temperature

- Potential falling risk: hypothermia risk at low temperatures

- Adapting recommendations: maintaining an optimal temperature during winter

Postural adaptations and temporal gait in elderly exposed to sliding

Adjusting walking stability while exposed to recurrent sliding, in view of reducing the backward balance, was recorded among young adults who experienced a sliding block before and after sliding.

The stability starting points for all types of sliding were obtained by shortening the landing distance (slide of the ipsilateral leg or arm) compared to the chondrolateral leg or arm, by measuring the center of mass (COM), the position and the relative speed of the base of support (BOS), as well as by using the mathematical prediction of the limit point for losing the backward balance.

The improvement of pre- and post-sliding stability was correlated with a decrease in the incidence of balance losses, from 100% (at the first slide) to 0% (at the fifth slide). For a short period of time, the improvement of pre-sliding stability was influenced by a proactive anterior shift in COM position. A significant improvement in post-sliding stability can be obtained by a reduction in the BOS perturbation intensity determined by a reduction in the demand on post-sliding onset braking impulse. This influences stability through proactive adjustments in the posture and gait pattern (position of the COM, step length, horizontal landing of the leg, increase in the knee flexion) before sliding.

The adapting control processes undergo a maturation process, defined by a support change in the control feed-back for posture correction, with an improvement of pre-sliding stability and of posture alteration intensity. The stability of the chondrolateral leg is a high predictor for incidental balance reduction (Bhatt et al., 2006).

Some surveys have been conducted to analyse whether the falling resistance learned during a single disturbance session can be maintained for six months, through additional sessions, among elderly people (aged over 65) living in the community. The initial disturbance exercise was conducted on all subjects, using a minimum friction platform in order to introduce an unannounced element by repeating the slide on the right side. There was one group session, repeated six months later. There was also a second group who had an extra sliding exercise three months after the initial one and then, the experience was repeated after six months. The following were assessed: result of sliding (falling incidence, balance loss), dynamic stability (based on the barycentre position and speed), vertical leg support (based on the hip height). Subjects from both groups had a significant drop in the falling and balance loss rate between the first and the last sliding exercise, showing an increase in stability and in the support leg control. Both groups proved to be able to remember significant information on all measuring results conducted after 6 months, compared to the first slides. The additional sliding exercises conducted at 3 months showed a better stability control and a drop in the balance loss rate. The movement memory can be kept for six months or more, after one single training session for falling resistance, although one single assisted fall may later stop the falling. Based on this sliding and falling experience, it is possible to "inoculate" the elderly against potential falls and their consequences (Bhatt et al., 2012).

Adults and elderly people who suffer from posture disorders that translate into missteps and sliding need to compensate these deficiencies quickly, in order to prevent the fear of falling. While tripping and falling, the ability to move one's torso is different in elderly people who fall compared to those who are afraid of falling. This ability can be quickly regained by the elderly, through specific task training. Acquiring new movement skills is associated with a lower risk of falling, during missteps. Falling prevention exercises, involving torso kinematics, will lead to a decrease in the falling rate and in the number of post-fall injuries among the elderly (Grabiner et al., 2008).

The lateral step initiation among the elderly was analysed and it showed various posture responses during voluntary or induced lateral step initiation. The cases where different stepping strategies were developed during lateral step initiations among the elderly were quantified and thus, the type of walking responsible for a history of recurrent falling was identified. 70 elderly people (with an average age of 76 years) participated in left/right voluntary lateral steps, trying to move as quickly as they could, as a reaction to a visual cue, within a blocked space. The vertical ground reaction force was measured with a force platform, the number and the latency of postural adjustments being thus quantified. The assessment was based on stepping strategies. The frequency of 1 or 2 adjustment trials was compared to the data collected from 20 young adults (average age – 38 years), the number of the falls recorded in the year previous to the one when the survey was conducted being correlated with the number and the latency of postural adjustments. Unlike the young adults, who almost always showed a postural adjustment during lateral stepping, the elderly subjects showed a continuous percentage variation in using one postural adjustment (from 0% to 100% per trial). The latency of the initial postural adjustment and the leg lifting varied, depending on the number of postural adjustments conducted. The falling history was largely associated with 2 posture adjustments and a higher latency in leg lifting. The number and the latency of postural adjustments conducted during lateral stepping are good indicators for lateral postural control among the elderly (Sparto et al., 2014).

The age-driven decay of the physiological components of balance control increases the risk of falling. The fear of falling translates into a high use of cognitive processes in order to select the right movements and the right stepping solutions.

The importance of cognitive tasks, as well as that of obstacles to stepping, affecting the initiation and the execution of the selection stages for stepping reactions, was analysed in young and elderly adults. Three groups were assessed: young adults (23-40 years old), elderly people with a low risk of falling (77-86 years old), and elderly people with a high risk of falling (78-88 years old). 4 circumstances were analysed: stepping choice, stepping selection and the presence of obstacles, stepping selection and memory involvement, stepping choice, memory involvement and the presence of obstacles. The stepping reaction time and the transfer time were measured for each circumstance, also adding hesitant stepping, obstacle contact and memory test errors. The elderly subjects showed a significantly longer reaction time and a longer transfer time than young adults. The reaction time and the transfer time were longer among those with a high risk of falling than among those with a low risk of falling. In terms of memory involvement, the reaction time was affected to a minimum among the young adults (7% increase), but it was significantly slowed down among the elderly people with a high risk of falling (over 48%), while among the elderly people with a low risk of falling it was recorded at an intermediate level (42%).

The presence of obstacles had a small but important impact on the reaction time (9.4%) and led to an increase in the transfer time (43.3 %), without, however, showing any difference between the groups. The number of errors made while taking steps, while performing secondary tasks or during obstacle contact increased with age, as well as the risk of falling. The elderly subjects exposed to a high risk of falling showed lower abilities to take correct voluntary steps, compared to the young adults, especially in the particular situations when their attention was divided (St George et al., 2007).

Compensatory stepping and grasping reactions have an important role in the sudden loss of balance and they play a crucial part in falling prevention. The ability to execute these reactions is impaired among the elderly. Balance disturbances were analysed during the training programme. An age-driven dysfunction was recorded, in terms of walking compensation and regaining the catching impulses during balance, among 30 elderly people (64-80 years) with a recent history of falling or self-supporting unbalance. Assessments were made at 6 weeks, focusing on balance disturbance (using a walking platform). A balance training programme was conducted and 6 weeks later, the increase in the flexibility and relaxation control was checked.

The perturbing programme was aimed at the following properties of balance reactions: multi-step reactions, extra-lateral steps following anteroposterior disturbances, foot collisions following side disturbances, time to complete grasping reactions.

The reactions were tested on an unpredictable, high translation surface. Compared to the control programme, the disturbance training showed significant decreases in the frequency of multi-step reactions and of foot collisions following side disturbances – statistically significant for the translation. A significant increase in the time of contact with the hand bar was recorded among the group tested on the translation surface, compared to the control group, without disturbance training (Mansfield et al., 2010).

The balance reactions and the hand catching movements made during fast walking are crucial for falling prevention. These compensating reactions are quicker than the volitional movements made by the legs and arms, thus becoming efficient in decreasing the centre of mass, in the case of movements triggered by unexpected balance disturbances.

The age-driven deterioration of the nervous, sensory and musculoskeletal systems can impair the ability to execute these specific reactions. There are several issues disturbing the side stability control while walking, among healthy elderly people: stopping the lateral body movement during backward or forwards steps and controlling the lateral movement of the leg, in order to prevent the collision between the moving and the supporting leg, during lateral steps. The elderly show a stronger faith in hand reactions than young people do, but they lose the capacity of executing quick catching reactions. The evaluation of the compensating steps and hand stretching reactions is important for identifying the individual risk of falling and for determining the specific balance-control issues, as well as for determining the necessary interventions during strength training. It is important to associate these issues with side stability control, side falls being responsible to a great extent for the occurrence of hip fractures (Maki et al., 2006).

Controlling the dynamic mediolateral stability during volitional stepping is a challenge for the elderly, this stability being largely responsible for falls and for the occurrence of hip fractures.

Young adults (24 years old) were compared to elderly people (71 years old) while performing 3 separate tasks comprising 1 step, at various speeds and step positions, with various challenges for setting dynamic stability. The trajectory of the total body centre of mass (COM) was calculated. The mediolateral inconsistency of the COM is different between the lateral and the final peak of the COM positions. The variation of this inconsistency was computed as an indicator of dynamic stability. The elderly people showed a higher dynamic instability compared to the young adults, translating into an increase of COM inconsistency. The higher alterations in the COM kinematics during the stepping initiation and the balance stage are a proof of stability issues (Singer et al., 2013).

Time pressure influences movement synchronisation and dynamic stability. The young adults and the elderly subjects conducted exercising series including quick leg flexions while standing, coupled with simultaneous extensions of the ipsilateral index, thus minimising the difference between the heel and finger movement onset.

This task was conducted twice, in two different circumstances: self-initiated (SI) and reaction time (RT). Time pressure changes the synchronising movements: finger extension happens before the heel balance in RT and the other way around in SI. The synchronising errors associated with the standard deviation were significantly higher among the elderly in SI, given the fact that self-perception is crucial for time-coordination.

On a secondary level, both groups showed a significantly shorter mediolateral anticipatory postural adjustment duration in RT (increased temporal pressure) compared to SI. This shortening was compensated by an increase in the anticipatory peak of centre-of-gravity (CoG) acceleration, during posture. This increased CoG acceleration was associated with an increased anticipatory peak of the mediolateral centre of pressure, shift towards the swing-leg, but only in young adults.

This ability to accelerate CoG, correlated with the centre-of-pressure, is impaired in the elderly people by:

insufficient leg muscles, a decrease in dynamic leg stability, thus leading to an increase in the risk of perturbing the mediolateral balance and in the risk of falling (Hussein et al., 2013).

With older age, the anterior stepping threshold, but not the posterior stepping threshold, is reduced. 30 young adults (31 years old) were compared to 11 middle aged adults (57 years old) and to 11 elderly people (73 years old). The testing surface was chosen in such a way that the subjects stayed on a moving carpet, operated by a microprocessor. The ability to execute the forward step decreases with age. A slight transfer disturbance among the middle aged and the elderly people is based on dynamic instability while initiating the step. Posterior stepping thresholds were not influenced by age (Crenshaw & Grabiner, 2014).

Side falling, very frequent among the elderly, is associated with a high risk of hip fracture, compared to other types of falling. Quick movements play an important functional role in balance keeping, side stepping requires a complex control and a moving load. Reactions to rapid stepping were analysed in healthy young adults (20-30 years) and elderly people (65-73 years) voluntarily exposed to an unpredictable sudden movement, on a platform. A video-analysis system described the walking pattern, through a side-walking platform. During lateral disturbances, while in static stage, the elderly were more prone to take multiple steps or to use their arm reactions in order to maintain their balance than the young adults were, especially during the walking transition stages. During walk-in-place trials, both young and older subjects more frequently used a sequence of side steps rather than crossovers; older adults were still more likely to take extra-steps or use arm reactions. In 55% of the walk-in-place trials conducted among the elderly, shocks were recorded between the leg balance and the stance limb, while among the young adults, the percentage was only 8%. Active and healthy elderly people seem to have difficulties in controlling their side stepping, before reporting problems in controlling their forward and backward stepping. Insufficient reactions aimed at controlling lateral stepping can be an early indicator of high lateral-falling risk and high hip fracture risk, thus being used in predicting and preventing falls and their consequences (Maki et al., 2000).

Testing the slipping resistance and determining the critical behaviour differences between assisted slips, up to the moment of complete after-fall recovery, are important components in falling prevention. Ground reaction forces at the shoe-floor interface are the most important biomechanical factor while slipping. The ratio of the shear to normal foot forces generated during gait, known as the required coefficient of friction (RCOF) if it is measured during normal movement on a dry surface and as “friction used/achievable” if it is measured while slipping, is a biomechanical variable closely associated with the measurements of the frictional properties of the shoe/floor interface.

Biomechanics depend on the system’s capacity to issue posture, mental, individual and environment perception control. Improving the frictions on the shoe/floor interface and improving walking safety lead to a decrease in the risk of slipping (Redfern et al., 2001).

Biomechanical analysis is necessary for researching the slipping components/for preventing falls. The unexpected occurrence of accidental slips in real life is a challenge for biomechanical surveys. The biomechanical changes of the gait were quantified among subjects exposed to an anticipated slippery environment. Foot ground reaction forces and the body dynamics were assessed in 16 subjects, during level walking and during downhill walking, with various friction properties and various declivity angles. Gait biomechanics were compared in three trials conducted on dry land: reference (subjects walking on a dry floor), anticipation (subjects who did not know exactly whether the floor was in various contamination stages – dry, contaminated with water, oil, soap, etc.), recovery trials after the contaminated trial (subjects who knew again that the floor was dry).

The anticipation trials produced the necessary peak required coefficient of friction (RCOF peak), reaching average values of 16-33%, significantly higher than the data collected during the reference trial and thus, reducing the slipping risk during the recovery trial. The RCOF peak did not go back to the reference value (5-12% lower).

The postural and temporal gait adaptations, which affected the ground reaction forces, were used to achieve RCOF (peak) reductions. The statistically significant gait adaptations included: reductions in stance duration and decreasing the supporting foot speed, shortening the normalized stride length, reducing the foot-ramp angle and slower angular foot velocity at heel contact. These adapting measures – the anticipation of a slippery surface, the significant changes in lower extremity joint moments – can be seen in the reactions recorded by muscles, in general, and they can decrease the slipping/falling risk (Cham & Redfern, 2002).

The lower extremity joint moments and the postural adjustments, as well as the correcting strategies adopted while slipping, were assessed in an attempt to prevent falling. The subjects walked on a slippery vinyl floor, with a ground reaction force and a body motion recorded at 350 Hz. The initiation of corrective body motion in an attempt to prevent falling became obvious at around 25% of the stance and it kept being visible up to around 45% of the stance, with an average between 190-350 ms, after heel contact. These reactions include: an increased flexion moment in the knee and extensor activity in the hip. The ankle is a passive joint (no net moment). The joint kinematics shows an increase in knee flexion and in the forward rotation of the leg, in an attempt to regain balance during falls. The ankle kinematics plays a less important role compared to the knee, in fall preventing attempts (Cham & Redfern, 2001).

The falling incidence can be decreased among elderly people by teaching them a better repositioning while adjusting their posture. The subjects (healthy elderly people and young adults) were exposed to induced slides, by use of a bilateral, low friction platform, while standing. They were exposed to 5 slides, in blocked non-slippery trials, with two repeated exposures to slipping. The first slip was new and unexpected. The effect of age on the groups, the incidence of falling (revealed by the excessive lowering of the hip) and the direction of the protective step taken were examined. After the first slip, the percentage of fallen people was higher among the elderly group than among the young adults, 73% vs. 28%. When repeating the slip, the percentage of those who fell dropped exponentially in both age groups. The subjects learned to slip without falling. There were repeated falls, without any change in the walking style, recorded for 63% of the falls. The percentage of those who fell later, when they were re-exposed to slipping, was still higher among the elderly (20% vs. 2%). In general, there were less accidental falls recorded than the initial number.

A forward or backward half-step ensures the success of recovery, by repeating the exposure and re-exposure to slipping, without significant differences between the age groups. The elderly are more prone to initial falling, due to unexpected disturbances but, when they are re-exposed to the same factors, both the healthy young adults and the elderly quickly learn to avoid falling. At the same time, healthy elderly people are capable of learning a better recovery through posture adjustments during repeated exposures (Pavol et al., 2002).

Conclusions

1. Age-related changes are defined, in terms of walking, by: a decrease in the hip extension peak (which is rather a dynamic phenomenon than a phenomenon encountered while standing), a higher outside hip flexion peak, a lower knee flexion, a decrease in the knee absorption powers while in pre-balance (both during comfortable and rapid speed walking), a reduction of the ankle plantar flexion, and a lower ankle-generated force.

2. The fall prevention programmes implemented so far are quite efficient, as they have reduced the number of falls by 14%, through multi-factor interventions. The interventions aimed at increasing safety at home are efficient in reducing the falling rate and the risk of falling.

3. Elderly people exposed to a high risk of falling show a significantly longer reaction time and a longer transfer time than young people do. The number of errors made while walking, while performing secondary tasks and during obstacle encounters increases with age, along with the risk of falling.

Conflicts of interest

Nothing to declare.

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