Chapter 6

Individual behaviour in the control of balance: the Balance control Difficulty Homeostasis model for falls among older persons

Wijlhuizen GJ, Schuller AA, Todd C, Zijlstra W, Zijlstra R, Hopman-Rock M.

Submitted
Abstract

Introduction
While it is important to prevent falls among older people from a public health point of view, older people themselves do not necessarily consider this important.

Method
This article describes the conceptual framework of a model for controlling balance and preventing falls: ‘the Balance control Difficulty Homeostasis model for falls among older persons’ (BDH model). The BDH model describes a homeostatic mechanism by which people strive to maintain a preferred safety margin between the capability to control balance and the demands made on this control of balance by physical activity.

Results
According to this model, a person modulates his/her behaviour, e.g.: changes walking speed, shifts attention, or avoids physical activity, on the basis of the perceived or anticipated difficulty in controlling balance and not primarily on the basis of the estimated likelihood of falling.

Conclusion
The BDH model suggests that a diminished capability to judge the difficulty of controlling balance and the acceptance of a smaller safety margin are factors that increase the probability of falling but do not prompt the individual to take specific measures to prevent falls. Implications for research and interventions are discussed.
Introduction

Many older people fall, and it is reported that about 33% people aged 65+ and up to 50% of women aged 85 years and older fall at least once a year.\textsuperscript{1,2} Falls, often defined as ‘An unexpected event in which the participants come to rest on the ground, floor or lower level’,\textsuperscript{3} may result in admission to a nursing home,\textsuperscript{4} increased fear of falling,\textsuperscript{5} serious injuries such as hip fracture,\textsuperscript{6} related high mortality and morbidity,\textsuperscript{6} higher costs of healthcare,\textsuperscript{7} and a reduced quality of life. From a public health point of view, falls prevention is an important issue,\textsuperscript{8} although older people themselves do not always consider this to be a priority issue. This lack of priority given to the prevention of falls is not fully understood\textsuperscript{9} and may result in poor participation in falls prevention programmes.

This article describes the conceptual framework of a new model, the Balance control Difficulty Homeostasis model for falls among older persons (BDH model), that takes into account the older person’s perception of how well balance can be controlled. The concepts are based on the ‘task-capability interface (TCI) model’ of Fuller.\textsuperscript{10}

The BDH model

General concepts

When a person falls, one or more risk factors have contributed to a situation in which that individual, without intention, loses control over their balance.\textsuperscript{11} Two general factors affect the control of balance. The first is the actual physical and mental capability to control balance, and the second represents circumstances or demands that affect this capability to control balance (e.g.: uneven pavements, darkness, high walking speed). In order to successfully control balance during physical activity, a person’s actual capability to control their balance has always to be higher than the situational demands made on this capability. The central issue is, how does a person manage to do this?

Analogous to Fuller’s TCI model\textsuperscript{10} we propose that in order to control balance, people need to make appropriate decisions about their physical activity performance, based on the ongoing perception of their capability to control their balance and the actual and expected demands of the situation in which they have to keep their balance. This ‘decision-making process’ for controlling balance occurs both automatically and consciously. For instance, a person with a limited capability to control their balance, who perceives an increased demand to control their balance (crowd of people closely passing by) will automatically tend to walk more slowly or will decide to avoid crowded areas in order to remain in control of their balance. Examples of the
interaction between a person’s perception of their capability and the demands made on this capability are given in table 1.

**Table 1**  Examples of scenarios describing a person’s loss of control of balance

<table>
<thead>
<tr>
<th>Person loses control of balance</th>
<th>Person does not lose control of balance</th>
</tr>
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<tbody>
<tr>
<td>An older person feels tired and has increasingly severe low-back pain after walking for an hour.</td>
<td></td>
</tr>
<tr>
<td>Walking home usually takes another 20 minutes.</td>
<td></td>
</tr>
<tr>
<td>Person loses control of balance Person does not lose control of balance</td>
<td></td>
</tr>
<tr>
<td>Usually the person rests; however, today visitors are expected. The person doesn’t take a rest</td>
<td>As usual, the person takes a rest, and if the pain doesn’t feel better, he/she usually takes a taxi or</td>
</tr>
<tr>
<td>and hurries to get home. The low back pain suddenly gets worse and the person does not lift their</td>
<td>bus to get home.</td>
</tr>
<tr>
<td>feet properly. The person hits a small obstacle on the pavement and loses control.</td>
<td></td>
</tr>
<tr>
<td>As usual, no rest is taken. The person is used to feeling tired and having low-back pain.</td>
<td>As usual, the person doesn’t take a rest. However, she/he pays special attention at well-known difficult</td>
</tr>
<tr>
<td>The temperature drops unexpectedly and the person’s legs and feet become cold. The person does</td>
<td>spots (road crossing, steep stairs uphill) and adjusts her/his walking speed.</td>
</tr>
<tr>
<td>not notice that he/she has become less flexible and he/she cannot compensate for a sudden small skid.</td>
<td></td>
</tr>
</tbody>
</table>

The BDH model (figure 1) describes the concepts and processes that are involved in the control of balance. Each concept is described below, starting from the top of the model. First, the distinction is made between the actual and the perceived difficulty of controlling balance. ‘Actual’ refers to the real difficulty of controlling balance when performing a physical activity and is based on the person’s physical and mental abilities and environmental conditions, and ‘perceived’ refers to a person’s anticipated difficulty of controlling balance while performing or planning a physical activity and is based on that person’s perception of their physical and mental abilities and their experience of similar situations.
Figure 1  The Balance control Difficulty Homeostasis (BDH) model for falls among older persons.

The model describes the Actual Balance control Difficulty (ABD) as a person is performing a physical activity (PA) that is equivalent with the ratio of Actual Capability (AC) and Demand (AD) to control balance. At the same time, the person perceives the Balance control Difficulty (PBD). In the PBD homeostatic mechanism, the person evaluates whether the PBD is within the range of acceptable PBD. If not, PA is modulated or avoided; otherwise PA is performed as planned. If during that activity AC exceeds the AD, no fall occurs; however, if AD exceeds the AC, loss of control of balance occurs resulting in a fall. All outcomes of the homeostatic mechanism may influence ABD as well as PBD.
**Actual Balance control Difficulty**

When performing a physical activity, the difficulty a person has in controlling their balance is equivalent to the ratio between that person’s capability to control their balance and the situational demands made on this capability. The closer the person’s capability to control their balance approaches the demands made on this capability, in other words, if the so called ‘safety margin’ becomes smaller, the more difficult it will be to control balance. However, it should be noted that the difficulty of controlling balance while performing an activity is not constant but instead fluctuates. It is affected by situational demands, such as the surface, light and weather conditions, the availability of handrails, etc, but also by the person’s actual psychological and physiological capability to control their balance, which also changes because the person may become fatigued or distracted while performing the activity.

**Perceived Balance control Difficulty (PBD)**

While a person does not know the actual difficulty of controlling balance, through observation and evaluation/assessment they will form an impression of, or perceive, the real difficulty. The level of perceived difficulty is inversely related to the difference between a person’s ongoing perception of their capability to control balance and the perceived demands. For instance, a person who experiences increasingly severe low back pain and tiredness while walking outside at dusk in a poorly lit environment perceives that it is increasingly difficult to control their balance. If a person notices that it is increasingly difficult to control their balance, the process of controlling balance will become more conscious and less automatic. Moreover, the person will perform fewer activities simultaneously; for example, they will stop to talk instead of talking while walking. The perceived difficulty of controlling balance may deviate from the actual difficulty, because the person may not have sufficient information to determine the actual difficulty of controlling balance; for instance, if they do not notice that part of the floor is slippery.

**Perceived Balance control Difficulty homeostasis mechanism**

A central mechanism of the proposed BDH model is that a person behaves in such a way as to keep the level of perceived difficulty of controlling balance within acceptable limits (target limits). According to the heuristic of perceived task difficulty, the perceived task (balance control) difficulty is compared to what is considered acceptable. If the perceived difficulty of controlling control balance is considered acceptable, the physical activity is performed as planned. If it is considered unacceptable, a strategy may be applied to modulate the perceived difficulty, that is,
the physical activity will be performed differently (e.g.: more/less cautiously, using a walking aid). However, if the perceived difficulty remains too high, the physical activity will be avoided.

The behavioural adjustments (modulations) are homeostatic in nature: they keep the perceived difficulty of controlling balance within an acceptable (to the person concerned) limit. This also implies that if the anticipated difficulty is below or at the low end of what is considered acceptable, a person may increase the perceived difficulty by, for example, climbing stairs without using the handrails, leaving walking aids at home while walking outside, or allowing themselves to carry a shopping bag.

**Consequences for Balance control**

If physical activity is avoided, no demands will be made on the capability to control balance; the person will not become out of balance and will not fall. Thus if a person often avoids physical activity, with time they will become less able to control balance because of a lack of experience and training (e.g.: loss of skill). This may lead to an increased actual and perceived difficulty of controlling balance.

If a person performs a physical activity and their capability to control balance exceeds the demands made on this capability, they will not fall. However, if a person overestimates their capability to control their balance and the situational demands exceed their capability to control balance, that person will lose control over their balance and fall. Depending on the resulting injury, that person's capability to control their balance may decrease, resulting in a greater perceived difficulty of controlling balance. Moreover, the person may no longer be able to perceive their capability to control balance accurately because it has decreased to a level that is unusual for the person. Even if a person is not injured by the fall, their perception of the difficulty of controlling their balance (fear of falling) may increase, and the physical activity may be avoided or a modulation strategy may be applied.

**Discussion**

From a public health point of view, the prevention of falls among older people is important because of the high incidence and serious consequences of falls. Yet older people appear not to be concerned about these issues because the uptake and adherence to falls prevention programmes is poor. The BDH model is based on the TCI model and emphasizes the importance of individual behavioural choices to the control of balance. Analogous to the TCI model, the BDH model assumes that older people control their balance primarily by adjusting their behaviour, based on the perceived difficulty of controlling balance and not on their own estimation of the...
probability of falling. As long as older people consider the perceived difficulty of controlling balance to be acceptable, they will not try to improve their capability to control balance even though their actual probability of falling is high. This may in part explain why many older people do not participate in falls prevention programmes.

Perceived balance control difficulty, fear of falling and physical activity

The BDH model assumes that if a person perceives the difficulty of controlling balance to be unacceptably high, that person will tend to reduce the demands made on their capability to control balance by, for example, avoiding physical activities. Fuller\(^{10}\) showed that the perception of task difficulty was strongly correlated with feelings of risk, which represent an emotional response to a threat, such as fear.\(^{16}\) The perception of task difficulty and fear appeared to be critical determinants of the behaviour of drivers (reducing speed). In an analogous manner, the BDH model predicts that the decision to be physically active is determined by the perceived difficulty of controlling balance and the emotional reaction to a threat, in this case fear of falling. Several studies have shown that a high level of fear of falling is associated with decreased physical activity in older people\(^{5,15,17-19}\) presumably modulated by a high perceived difficulty of controlling balance. This latter relationship was studied recently (unpublished data) among 333 community-dwelling older people (75+), who were asked in a questionnaire to rate the difficulty of controlling balance for several physical activities (such as, walking, climbing stairs, taking a shower). Analysis revealed that a greater difficulty of controlling balance was associated with a lower frequency of actually performing these activities. In addition, some studies have reported a diminished fear of falling and increased physical activity in older people participating in physical exercise programmes,\(^{20,21}\) possibly as an increased capability to control balance. These results support the assumed relationship between an emotional reaction to a threat (e.g.: fear of falling), perceived difficulty of controlling control balance, and behavioural modulation. They also support the concept of the homeostatic nature of human behaviour in relation to fear of falling, but this needs further verification in empirical studies of each concept, not only for the level of physical activity, but also for other modulation strategies such as using walking aids, handrails or avoidance of certain areas with uneven pavements or crowds of people.

Adequacy of perception of the actual balance control difficulty

In the BDH model, an accurate perception of the actual difficulty of controlling balance determines whether a person loses control of body posture. The accuracy of this perception is decreased if the actual capability to control balance and the demands made on this capability fluctuate, or if a person’s mental functioning is reduced.
Physically frail older people with a high fall risk not only appear to have a diminished capability to control their balance but also have a relatively high number of transitions as they become less mobile. In addition, the haemodynamic and neuromusculoskeletal changes that occur when a person changes position may reduce a person’s capability to control their balance. If the person does not perceive or underestimates these changes, they may underestimate the difficulty of controlling their balance and subsequently fall.

However, older people may realize that their actual capability to control their balance is becoming unpredictable. In this situation, accurate perception and estimation of the demands made on balance control will become more important. Perception of these demands will improve if unexpected fluctuations in the demands are reduced, which could explain why frail older people limit their activities to familiar environments and as a result become less physically active.

Various studies have shown that dementia and the use of psychotropic medication are risk factors for falls. These results also support the assumption that a diminished perception of the difficulty of controlling balance is associated with falls.

Acceptance of the perceived balance control difficulty

The BDH model assumes that individuals “set” limits to what they consider an acceptable perceived difficulty of controlling balance. In general, individuals prefer to have a relatively broad margin of safety between the demands made on their capability to control balance and their real capability. However, many older people perceive the difficulty of controlling balance during the performance of physical activities to be high. Some show signs of a deterioration of balance control, such as reduced step length and walking speed, increased visual control during walking, signs which may be regarded as indicators of a small safety margin between the capability to control balance and the demand. Why then, do these older people still perform physical activities even if they perceive the safety margin to be very small?

Three psychological mechanisms undermine the maintenance of safety margins. First, motivational conditions, such as living independently, undermine the maintenance of safety margins because certain essential physical activities with a fixed level of demand have to be performed, even if the capability to control balance is diminished. Second, a growing desensitization to potential threats may occur if the threats are not realized. Although the perceived difficulty of controlling balance will gradually increase, the person may negate this increased difficulty if they do not lose their balance and fall. Finally, even if a person loses their balance and falls, this is considered to be a rare event by most older people, perhaps occurring once a year at most. Indeed, an individual may have performed ‘dangerous’ activities in the past.
without deleterious consequences, and it seems that older people often base their perceptions within the context of their whole life, rather that the current period of reduced capability. For these reasons, older people may not feel it worth their time, money, and energy to participate in falls prevention programmes.

Implications

Although support for the BDH model can be found in the literature on falls, the homeostatic mechanism and related acceptable target levels of task difficulty require further study. Thus the model should be considered as a conceptual framework that needs further research-based testing and refinement. Nevertheless, the model has implications for research and practice in risk assessment and falls prevention among older people.

The model describes several mechanisms that contribute to explaining why older people will not feel the need to take specific preventive measures against falls. Older people experience that they can control their balance quite adequately by changing the level of physical activity. Moreover, older people tend to accept a smaller safety margin between the capability to control balance and the demands made on them to control their balance, and become less accurate in estimating the difficulty of maintaining their balance. Thus in order to assess the actual impact of risk factors for falls, estimation of the fall risk should include the level of physical activity as a measure of exposure, because older people reduce their level of activity; thereby increasing their balance control and in fact prevent falls. As reducing physical activity may subsequently lead to a further reduction in the capability to control balance, falls will start to happen if people are not able to reduce their physical activity to a level that is consistent with their capabilities. The focus of an intervention strategy for falls prevention should therefore be primarily to maintain or increase the capability to control balance before falls actually start to happen. Moreover, if the capability to control balance is diminished by illness or immobility, steps should be taken to increase this capability in a safe environment, where the person can accurately estimate the demands made on them. Lastly, if falls prevention programmes focus on older people, they may reduce their level of physical activity because of a fear of falling, or they might misunderstand the message because they do not consider themselves to be at risk of falling, feeling confident in their capability to control their balance. Therefore, the issue of falls prevention should be primarily addressed to professionals who are involved in healthcare and welfare of older persons. These professionals should screen, and if necessary treat, those factors related to emerging gait and balance problems before older people start to reduce their physical activity and in the end lose control of their balance.
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**Literature**


8. Skelton D, Todd C. What are the main risk factors for falls amongst older people and what are the most effective interventions to prevent these falls? How should interventions to prevent falls be implemented? Copenhagen, Denmark, 2004. World Health Organisation. HEN Health Evidence Network; Evidence for decision-makers.


25. Tracy BL, Enoka RM. Older adults are less steady during submaximal isometric contractions with the knee extensor muscles. J Appl Physiol 2002; 92:1004-1012.


