CHAPTER 7

Adaptability treadmill training, conventional treadmill training and usual physical therapy in older adults after fall-related hip fracture: a randomized controlled trial of participants’ attitudes and amount of walking practice

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Abstract

**Background.** The ability to make step adjustments to environmental context during walking is often reduced in older adults, a population in which falls are common. We evaluated the attitude of older adults towards walking adaptability training using a treadmill augmented with projected visual context (i.e., obstacles and targets), and compared the amount of walking practice during this training with conventional treadmill training and usual physical therapy.

**Methods.** In a parallel group, open randomized controlled trial, seventy older adults with a fall-related hip fracture (83.3±6.7 years) were block randomized to six weeks inpatient adaptability treadmill training \((n=24)\), conventional treadmill training \((n=23)\) or usual physical therapy \((n=23)\). After the intervention period, participants’ attitude towards the intervention was evaluated using a purpose-designed questionnaire on experienced usefulness, motivation, fun, challenge, enjoyment (rated from 1 [low] to 10 [high]) and perceived discomfort. The amount of walking practice during adaptability and conventional treadmill training was defined as the number of steps performed per training session, as registered by an instrumented treadmill. The number of performed steps per session of usual physical therapy was assessed manually by two observers in an additional comparison group of 16 older adults (85.1±6.3 years).

**Results.** All three training groups rated the received training favorably with median scores of 7.0 or higher for usefulness, motivation, fun, challenge and enjoyment, with no significant differences between groups (all \(p>0.397\)). Participants in the adaptability treadmill \((803.4 \ [426.1–1,174.5] \text{ steps})\) and conventional treadmill \((847.8 \ [416.8–1,415.5] \text{ steps})\) groups performed significantly more steps per training session on the treadmill than the additional comparison group per session of usual physical therapy \((368.0 \ [135.0–1,179.5] \text{ steps}, \text{ both } p<0.001)\).

**Conclusion.** Adaptability treadmill training, conventional treadmill training and usual physical therapy were all well received by older adults with fall-related hip fracture. Adaptability and conventional treadmill training led to more walking practice per session than usual physical therapy, without a difference between both treadmill-based interventions. Future research should compare the efficacy of the three forms of training for improving older adults’ walking ability and fall incidence.
Background

The number of people above 65 years of age is increasing rapidly in the Western world [1]. Ageing is associated with increased gait and balance problems [2, 3], placing older adults at an increased risk of falling [4, 5]. Falls mostly occur during walking and are common events in older adults [6, 7], which may have serious consequences, including fractures, soft tissue injury, fear to fall again, inactivity and even death [7-9].

Safe ambulation requires the ability to make step adjustments during walking in response to environmental demands, such as when avoiding obstacles. This ability is impaired in older adults [10, 11], as reflected in the fact that environmental hazards are involved in approximately half of all falls [6-8]. Walking adaptability thus seems an important factor to improve in older adults. During the last decade or so, several therapeutic devices have been developed specifically for this purpose. Among these is the C-Mill (ForceLink, Culemborg, the Netherlands), an innovative, instrumented treadmill augmented with projected visual context, such as obstacles and targets [12]. The C-Mill uses projected visual context to elicit step adjustments during treadmill walking based on individual gait characteristics, enabling individually tailored task-specific training with direct feedback on gait characteristics and the successfulness of interactions with environmental context. In addition to these key components for effective gait rehabilitation [13, 14], the C-Mill contains game elements such as interactive feedback, a scoring system and an online pedometer to create a stimulating practice environment.

New technologies such as the C-Mill, but also virtual reality and interactive video games, are increasingly used as therapeutic tools in older adults [15-19]. These interactive technologies are generally believed to enhance enjoyment and motivation with training [20-22], and thus to promote uptake and adherence to training as essential requisites for its efficacy [23]. However, little is known about the attitude of older adults towards these new technologies [24, 25]. Several studies have reported on the perceived level of enjoyment during interactive video gaming in older adults [17, 19, 24, 25], but mostly only as a side issue [17, 19], or without using a control group [17]. Even less is known about treadmill-based interactive technologies in this regard. In order to develop training programs that are not only effective but also well accepted and well received by older adults, it is important to gain more insight into older adult’s perceptions of such technologies, as has been highlighted by Hawley-Hague et al. [26] in a broader context.
An important factor for effective rehabilitation is the amount of task-specific practice [13, 14, 27]. C-Mill adaptability treadmill training combines walking adaptability exercises with treadmill walking, which is a widely used type of training in different patient populations. Treadmill walking is deemed to evoke a greater number of gait cycles practiced per treatment session compared to overground gait training (e.g., after hip fracture or replacement [28, 29], stroke [30-33] and spinal cord injury [34]), but this has only been quantified objectively in a small number of studies. In particular, four studies reported three to ten times as many steps for treadmill training than for overground training [29, 32, 34, 35]. However, the extent to which interactions with visual context affect the number of steps performed during adaptability treadmill training is currently unknown.

Therefore, the present superiority trial compared the attitude of older adults towards adaptability treadmill training, conventional treadmill training and usual physical therapy and compared the amount of walking practice for these three forms of training in order to evaluate the assumption of increased amounts of walking practice underlying (adaptability) treadmill training. With regard to attitude we expected the most positive attitude towards adaptability treadmill training, given its functional and interactive practice environment, followed by usual physical therapy and finally conventional treadmill training for its repetitive, somewhat monotonous, character. For the amount of walking practice we expected the number of steps performed per training session to be greater for both treadmill-based interventions than for usual physical therapy. No differences were expected in the number of performed steps per training session between adaptability treadmill training and conventional treadmill training.

**Methods**

**Participants**
Seventy older adults with a fall-related hip fracture were recruited from residential and rehabilitation center Zorggroep Solis in Deventer, the Netherlands between January 2012 and December 2014. All participants took part in a larger parallel group, superiority randomized controlled trial with pre-tests, post-tests, retention tests and follow-up, aimed to evaluate the efficacy of adaptability treadmill training for improving walking ability, fear of falling and fall incidence (see [15] for the study protocol and the Netherlands Trial Register [NTR3222] for trial registration). Inclusion criteria for participation in the trial were admission with a hip fracture related to falling, ≥65 years of age, Functional Ambulation Category score 2 or
higher (FAC [36, 37]), expected duration of admission ≥ 6 weeks and an ability to understand and execute simple instructions. Exclusion criteria were not being allowed to bear weight on the affected leg, moderate or severe cognitive impairments as indicated with a score below 18 at the Mini-Mental State Examination (MMSE [38]), severe non-corrected visual impairments limiting the correct perception of the direct environment, contraindication to physical activity and an activity tolerance below 40 minutes with rest intervals. Participants were block randomized to six weeks of inpatient adaptability treadmill (AT) training (n=24), conventional treadmill (CT) training (n=23) or usual physical therapy (UPT, n=23) and data analyses included all participants who had completed at least 4 weeks of the allocated intervention. An additional comparison (AC) group receiving usual physical therapy (n=16) was included to be able to quantify the number of steps performed during usual physical therapy, as this was not registered for participants in the UPT group for practical reasons. The AC group consisted of a convenience sample of 16 older adults above 65.0 years of age, with a FAC score of 2 or higher, who received physical therapy for a recent hip fracture between April and October 2013 at the same center. All participants gave written informed consent and the study protocol was approved by the Medical Ethical Reviewing Committee of VU University Medical Centre, Amsterdam, the Netherlands. The study protocol for the AC group did not fall within the Medical Research Involving Human Subjects Act as declared by the same medical ethics committee.

Sample size calculation indicated that 15 participants per group were needed to detect a significant difference of 250 steps between both treadmill training groups on the one hand and the AC group on the other hand, with a standard deviation of 200, 80% power and a two-tailed α of 0.01 that was corrected for multiple comparisons. With respect to the attitude towards training, this sample size was sufficient to show a relative difference of 1.3 points between groups on the numerical rating scale with a standard deviation of 1.0 point.

**Procedures and intervention**

Figure 7.1 shows a flow chart of the study procedures. Although numerous tests were administered at multiple measurement times in the course of the trial [15], the present study focused on older adults’ attitude towards the three forms of training and the amount of walking practice. After inclusion in the trial, participant characteristics were collected (Table 7.1), including mobility (Performance Oriented Mobility Assessment; POMA [39]), executive function (the Trail Making Test part A and B; TMTa and TMTb, [40]), type of hip fracture, comorbidities and
Attitudes and amount of practice during adaptability treadmill training

pre-fracture living situation (i.e., whether or not living independently without assistance for showering). Subsequently, participants were allocated to six weeks of inpatient AT training, CT training or UPT. The six-week intervention period comprised 30 training sessions (i.e., five sessions per week) of 40 minutes each. Training sessions were conducted by physical therapists, typically with two participants supervised by one physical therapist. Participants alternately practiced and rested during training sessions, resulting in 20 minutes of practice for each participant. Physical therapists and participants were inevitably not blinded to group allocation. At the end of the intervention period, participants’ attitude towards the intervention was evaluated face-to-face by the physical therapist using a purpose-designed questionnaire directed solely at the AT, CT or UPT training sessions (Additional file 1, page 144-154). In most cases, participants self-administered the questionnaire after a short instruction by the physical therapist. If participants were not able to fill out the questionnaire themselves, the physical therapist read the questions and possible answers to the participant and recorded the given answer. The first part of the questionnaire consisted of questions regarding experienced usefulness, motivation, fun, challenge and enjoyment with the intervention, rated on a 10-point numerical rating scale (1 being low and 10 being high). For the AT and CT groups, this part of the questionnaire also included questions regarding their initial level of reserve with the intervention, their experienced relevance of the intervention for older adults and their recommendations for peers. We used the 10-point numerical rating scale, since this is a valid, reliable, simple and easy to use scale that is appropriate for use in clinical practice and can be administered graphically as well as verbally [41, 42]. The 10-point numerical rating scale is also well known and widely used in the Netherlands, for example in the Dutch education system. Our participants were thus well acquainted with the scale, which helped to understand and fill out the questionnaire in an appropriate and efficient manner. The second part of the questionnaire included questions regarding perceived discomfort during and after training sessions, rated on a 3-point ordinal scale (i.e., no discomfort, one-time discomfort and frequent discomfort). Perceived discomforts had to be described and participants in the AT and CT groups reported whether they had also experienced these discomforts during and after the sessions of usual physical therapy they had received. For the AT group, two additional questions were included in the questionnaire to evaluate which walking adaptability exercises were rated “easy” and which “difficult” (multiple answers were possible). Note that all questions in the questionnaire were administered at the end of the intervention period only.
Included and randomized after pre-test and collecting participant characteristics \((n=70)\)

6 weeks of AT training \((n=24)\)
- Number of steps and walking duration were registered with the instrumented treadmill
- Completed \(\geq 4\) weeks of intervention \((n=19)\)
  - Dropped out \((n=5)\)
    - Early discharge home \((n=3)\)
    - Transfer to other nursing home \((n=2)\)
  - Filled out questionnaire on attitude \((n=18)\)
    - Unable due to cognitive problems \((n=1)\)

6 weeks of CT training \((n=23)\)
- Number of steps and walking duration were registered with the instrumented treadmill
- Completed \(\geq 4\) weeks of intervention \((n=17)\)
  - Dropped out \((n=6)\)
    - Early discharge home \((n=2)\)
    - Perceived intervention as unpleasant \((n=1)\)
    - Illness \((n=2)\)
    - Death \((n=1)\)
  - Filled out questionnaire on attitude \((n=17)\)

6 weeks of UPT \((n=23)\)
- Completed \(\geq 4\) weeks of intervention \((n=21)\)
  - Dropped out \((n=2)\)
    - Experienced stress with participation \((n=1)\)
    - Complications regarding hip fracture \((n=1)\)
  - Filled out questionnaire on attitude \((n=21)\)

Additional comparison group (AC): collecting participant characteristics \((n=16)\)

Single session of UPT \((n=16)\)
- The number of steps was counted by two observers and with two pedometers. Walking duration was registered using a stopwatch

Filled out questionnaire on attitude \((n=18)\)
- Unable due to cognitive problems \((n=1)\)

Figure 7.1 Flow chart of the study procedures. Abbreviations: AT-adaptability treadmill, CT-conventional treadmill, UPT-usual physical therapy, AC-additional comparison.
Participants in the UPT control group received conventional physical therapy in all 30 training sessions, which comprised exercises of overground walking, daily living activities, transfers, but also exercises for balance and upper-leg strength. These UPT training sessions followed locally implemented guidelines regarding the treatment of hip fractures.

For the CT group, half of UPT training sessions were replaced with conventional treadmill walking at comfortable walking speed without body weight support other than using the handrails. Comfortable treadmill walking speed was determined by the physical therapist as the walking speed that led to safe and high quality walking, and was reported comfortable by the participant. The number of steps performed during each CT training was registered using an instrumented treadmill (i.e., the C-Mill without visual context projected on the belt’s surface), which is a reliable tool for detecting gait events (e.g., foot contact and foot off) and gait characteristics (e.g., step length, step width, cadence; [43]). This was also confirmed by pilot data showing reliable limits of agreement between the number of steps registered with the treadmill’s inbuilt pedometer and by an observer who manually counted the steps; the between-method difference in the number of steps was only -3.2 to 2.9 steps in 95% of the observations [44]. Although training sessions were typically 20 minutes, the actual time spent walking during each training session was also registered using the instrumented treadmill and was recorded in a training log by the physical therapist. This was done to control for the effect of walking duration on the number of performed steps per training session.

The AT training program was similar to that of the CT group but with a strong emphasis on practicing step adjustments to projected visual context during treadmill walking (Figure 7.2 and Additional file 2 [i.e., a video available at https://youtu.be/5SLQp4hAVFk], see page 155). Walking adaptability exercises comprised visually guided stepping to a sequence of regularly or irregularly spaced stepping targets with or without targets changing to obstacles (Figure 7.2B), obstacle avoidance (Figure 7.2C), speeding up and slowing down by following a projected walking area of approximately 1 m² that oscillated in anterior-posterior direction over the treadmill surface (Figure 7.2D) and walking adaptability games consisting of interactive stepping targets (e.g., beach balls) and obstacles (e.g., seals, shells, crabs) (Figure 7.2E). The number of steps performed during each AT training sessions was again registered using the instrumented treadmill and recorded in a training log by the physical therapist, as was walking duration (i.e., the actual time spent walking). The three interventions have been previously described in more detail [15].
Figure 7.2 C-Mill walking adaptability exercises. The C-Mill is an instrumented treadmill augmented with projected visual context (A). Walking adaptability exercises include visually guided stepping to a sequence of regular or irregular stepping targets (B), obstacle avoidance (C), speeding up and slowing down by following a moving walking zone (D), and interactive walking adaptability games (E).

Note that for participants of the AT and CT groups, only the treadmill-based training sessions (and hence not the sessions of usual physical therapy these participants also received) were included when evaluating the number of performed steps and the attitude towards training. For practical reasons the number of performed steps was not registered for participants in the UPT group. Instead, an additional comparison (AC) group was included to estimate the amount of walking practice during usual physical therapy. Their participant characteristics (i.e., age, height, gender, comorbidities and FAC score) were collected before the start of a regular session of usual physical therapy that was performed at a convenient moment in their rehabilitation process. These were used to evaluate whether participants in the AC group were representative of those in the six-week intervention trial. For this reason, also post-intervention FAC scores were administered in AT, CT and UPT groups. Participants in the AC group were equipped with two wearable pedometers (Yamax Digiwalker, Yamax Health & Sports Inc., San Antonio, USA) and subsequently received a session of usual physical therapy. In addition, two observers manually counted in real time the
number of steps that the participants performed during this single session of usual physical therapy, since the accuracy of commonly used body-worn pedometers has been shown to decrease at lower walking speeds [45], which was anticipated to be the case in this group of older adults [46, 47]. The actual time spent walking per session of usual physical therapy by participants in the AC group was registered using a stopwatch. We decided to measure the number of steps during usual physical therapy sessions in an AC group since the physical therapy sessions in the UPT group were too much spread over time. It was financially and time-wise impractical to manually count the number of steps by two observers at many different days. The protocols for physical therapy were similar for AC and UPT groups; both followed locally implemented guidelines regarding the treatment of hip fractures.

Data analysis
Participant characteristics were compared between AT, CT and UPT groups using either parametric One-Way ANOVAs (age, height, body mass and POMA) or non-parametric Fisher’s exact tests (gender, type of fracture, comorbidities, pre-fracture living situation and TMTb [in proportion of participants who completed the test within 5 minutes]) and Kruskal-Wallis tests (MMSE, FAC, TMTa [in seconds]). Participant characteristics were further compared between participants who dropped out and those who completed at least four weeks of training and between participants in the AC group and those in the six-week intervention trial (i.e., AT, CT and UPT groups together) using parametric independent t-tests or non-parametric Fisher’s exact and Mann-Whitney U tests.

Attitude towards training and the number of steps performed per training session comprised the primary statistical analyses of the present study. Attitude towards training was compared between AT, CT and UPT groups by means of Kruskal-Wallis tests on the ratings for experienced usefulness, motivation, fun, challenge and enjoyment, which are ordinal data. Ratings that were only available for AT and CT groups (i.e., initial level of reserve, relevance for older adults and recommendation for peers) were compared using Mann-Whitney U tests. When participants marked two ratings for one question, the average of both was used for statistical analysis (3 questions), and when participants circled the scale’s description instead of the rating, the rating was excluded from the analysis (1 question). The number of participants who perceived discomforts during and/or after training sessions were also compared between AT, CT and UPT groups using
Kruskal-Wallis tests and descriptive statistics were used to report which C-Mill walking adaptability exercises were rated “easy” and which were rated “difficult”.

For each participant in the AT and CT group, the number of performed steps per training session was averaged over all training sessions. To control for the time spent walking per training session, this was also done for walking duration. Training parameters incorrectly recorded during a training session (for example due to technical errors) were not included in the average of that training parameter (for both training parameters: <6% of all training sessions was excluded). For the AC group, the average of the steps counted by the two observers was used for further analysis, because the spring-lever pedometers showed to be inaccurate in our sample as evidenced by wide limits of agreement (i.e., 95% of the differences between the two pedometers was between -269 and 353 steps, whereas the difference between the number of steps counted by two observers was only between -21 and 20 steps in 95% of the observations [44]). The number of performed steps and walking duration per training session were compared between AT, CT and AC groups using either parametric One-Way ANOVAs or non-parametric Kruskal-Wallis tests in case of non-normally distributed data as evaluated using Shapiro-Wilk tests. Post hoc analyses included independent t-tests or Mann-Whitney U tests.

All statistical tests were two-tailed and performed in SPSS 21 (SPSS Inc, IBM Corporation, New York, USA). Results are reported as frequency (proportion) for nominal data, as median (minimum-maximum) for ordinal or non-normal interval data and as mean±standard deviation for normally distributed interval and ratio data. The level of significance was set at \( p<0.05 \) for the main analyses and at \( p<0.01 \) for post hoc tests to correct for the multiple comparisons. Effect sizes of the intervention are presented as eta squared (\( \eta^2 \)) for One-Way ANOVA. Effect sizes for Kruskal-Wallis tests were not reported, because straight effect size measures are not available for this test. However, effect sizes of the associated post hoc Mann-Whitney U tests are reported as \( r \) [48].

**Results**

A total of 70 participants were randomly assigned to the three training groups (AT, CT, UPT), 57 of whom completed at least four weeks of training (Figure 7.1 shows group distributions and reasons for dropout). Table 7.1 shows the participants’ characteristics, which were not significantly different among the three training groups except for gender and the presence of urogenital disorders. The
characteristics of the participants who dropped out were not significantly different from those who completed at least four weeks of training (all $p>0.157$), except that the participants who dropped out tended to be older (dropouts: 86.2±5.6, non-dropouts: 82.7±6.7 years, $t(68)=1.774$, $p=0.080$). Out of the 30 specified training sessions, AT and CT groups performed respectively 11 (8-15) and 12 (7-14) training sessions on the treadmill and 13 (7-18) and 12 (7-15) sessions of usual physical therapy. The UPT group performed 27 (16-31) sessions of usual physical therapy.

The participants in the AC group were representative of those in the six-week intervention trial (i.e., AT, CT and UPT groups together) in terms of age, height and gender, but differed for certain co-morbidities (i.e., fewer cardiovascular/respiratory diseases and more musculoskeletal disorders; Table 7.1). FAC scores in the AC group (3.0 [2.0-5.0]; supervision during level walking) were significantly higher than those in the six-week intervention group at baseline (2.0 [2.0-4.0]; manual contact during level walking, $U=323.0$, $p=0.006$, Table 7.1), but significantly lower than those in the six-week intervention group after the intervention period (4.0 [2.0–5.0]; independence during level walking, $U=258.0$, $p=0.005$).

**Attitude towards training**

Participants in the three training groups rated the training favorably in terms of usefulness, motivation, fun, challenge and enjoyment, with median scores of 7.0 and higher on all items (Figure 7.3). No significant differences were observed among groups (all $\chi^2(2)<1.876$, all $p>0.397$). Participants in the AT and CT training groups rated their initial reserve with the training with scores of respectively 6.0 (1.0-8.5) and 6.0 (2.0-10.0). The training’s relevance for older adults and the recommendation for peers were both rated with 7.0 (5.0-10.0, $n=17$ for recommendation for peers) in the AT group and with 8.0 (3.0-10.0) in the CT group. No significant differences between AT and CT groups were observed (all $U\geq101.0$, all $p>0.129$, all $r<0.264$). With regard to the difficulty of C-Mill exercises, visually guided stepping (frequency [proportion]: 12 [66.7]) and obstacle avoidance (8 [44.4]) were most frequently rated as “easy”, whereas visually guided stepping with stepping targets changing to obstacles (6 [33.3]) and the fun and functional walking adaptability game (4 [22.2]) were most frequently reported as “difficult”.

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Table 7.1 Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>AT (n=24)</th>
<th>CT (n=23)</th>
<th>UPT (n=23)</th>
<th>p value&lt;sup&gt;a&lt;/sup&gt;</th>
<th>AC (n=16)</th>
<th>p value&lt;sup&gt;b&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>82.9±6.5</td>
<td>83.9±5.5</td>
<td>83.3±8.0</td>
<td>0.877&lt;sup&gt;c&lt;/sup&gt;</td>
<td>85.1±6.3</td>
<td>0.334&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Height, m</td>
<td>168.6±9.6</td>
<td>166.8±10.8</td>
<td>166.2±8.3</td>
<td>0.691&lt;sup&gt;e&lt;/sup&gt;</td>
<td>164.6±7.8</td>
<td>0.324&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Body mass, kg</td>
<td>72.3±14.7</td>
<td>71.4±12.7</td>
<td>68.7±16.7</td>
<td>0.695&lt;sup&gt;e&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Gender, n male (%)</td>
<td>8 (33.3)</td>
<td>9 (39.1)</td>
<td>2 (8.7)</td>
<td><strong>0.047&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td>2 (12.5)</td>
<td>0.336&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Comorbidities</td>
<td></td>
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<tr>
<td>Cardiovascular/</td>
<td></td>
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<tr>
<td>Respiratory diseases, n (%)</td>
<td>21 (91.3)</td>
<td>19 (82.6)</td>
<td>19 (82.6)</td>
<td>0.755&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9 (56.3)</td>
<td><strong>0.015&lt;sup&gt;d&lt;/sup&gt;</strong></td>
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<tr>
<td>Gastrointestinal</td>
<td>2 (8.7)</td>
<td>4 (17.4)</td>
<td>5 (21.7)</td>
<td>0.598&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1 (6.3)</td>
<td>0.449&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>disorders, n (%)</td>
<td>6 (26.1)</td>
<td>3 (13.0)</td>
<td>0 (0.0)</td>
<td><strong>0.034&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td>0 (0.0)</td>
<td>0.198&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Urogenital disorders, n (%)</td>
<td>9 (39.1)</td>
<td>5 (21.7)</td>
<td>5 (21.7)</td>
<td>0.353&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10 (62.5)</td>
<td><strong>0.017&lt;sup&gt;d&lt;/sup&gt;</strong></td>
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<tr>
<td>Musculoskeletal</td>
<td>5 (21.7)</td>
<td>6 (26.1)</td>
<td>4 (17.4)</td>
<td>0.933&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5 (31.3)</td>
<td>0.514&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>disorders, n (%)</td>
<td>1 (4.3)</td>
<td>2 (8.7)</td>
<td>3 (13.0)</td>
<td>0.865&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0 (0.0)</td>
<td>0.589&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Neurological disorders, n (%)</td>
<td>6 (26.1)</td>
<td>8 (34.8)</td>
<td>11 (47.8)</td>
<td>0.346&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6 (37.5)</td>
<td>1.000&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Psychiatric disorders, n (%)</td>
<td>0 (0.0)</td>
<td>1 (4.3)</td>
<td>0 (0.0)</td>
<td><strong>1.000&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td>0 (0.0)</td>
<td>1.000&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Other, n (%)</td>
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<tr>
<td>Functional Ambulation Category, FAC</td>
<td>2.0 (2.0-4.0), n=23</td>
<td>2.0 (2.0-4.0)</td>
<td>2.0 (2.0-4.0)</td>
<td>0.200&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.0 (2.0-5.0)</td>
<td><strong>0.006&lt;sup&gt;e&lt;/sup&gt;</strong></td>
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<tr>
<td>Type of fracture</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Cervical, n (%)</td>
<td>11 (45.8)</td>
<td>11 (47.8)</td>
<td>8 (34.8)</td>
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<td></td>
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<tr>
<td>Trochanteric, n (%)</td>
<td>12 (50.0)</td>
<td>12 (52.2)</td>
<td>14 (60.9)</td>
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<tr>
<td>Subtrochanteric, n (%)</td>
<td>1 (4.2)</td>
<td>0 (0.0)</td>
<td>1 (4.3)</td>
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<tr>
<td>Pre-fracture living situation, n living independent (%)</td>
<td>21 (87.5)</td>
<td>16 (70.0)</td>
<td>18 (78.3)</td>
<td>0.312&lt;sup&gt;d&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Mini Mental State Examination, MMSE</td>
<td>25.0 (19.0-30.0), n=23</td>
<td>26.0 (22.0-30.0)</td>
<td>27.0 (22.0-29.0)</td>
<td>0.342&lt;sup*e&lt;/sup&gt;</td>
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<tr>
<td>Performance Oriented Mobility Assessment, POMA</td>
<td>15.6±2.8</td>
<td>15.5±3.6</td>
<td>15.6±4.1</td>
<td>0.994&lt;sup&gt;d&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Trail Making Test-part A, TMTa, s</td>
<td>15.0 (41.0-269.0)</td>
<td>99.0 (47.2-188.0)</td>
<td>85.0 (27.0-177.0), n=21</td>
<td>0.857&lt;sup&gt;*&lt;/sup&gt;</td>
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<tr>
<td>Trail Making Test-part B, TMTb, n completed within 5 min (%)</td>
<td>15 (65.2)</td>
<td>14 (60.9)</td>
<td>15 (65.2)</td>
<td>0.860&lt;sup&gt;*&lt;/sup&gt;</td>
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<sup>a</sup>p values represent the comparison between adaptability treadmill training (AT), conventional treadmill training (CT) and usual physical therapy (UPT) groups. <sup>b</sup>p values represent the comparison between the additional comparison (AC) group and the six-week intervention group (i.e., AT, CT and UPT groups combined). Statistical analyses included One-Way ANOVAs, Fisher’s exact tests, Kruskal-Wallis tests, independent t-tests and Mann-Whitney U tests. Significant differences are presented in bold (p<0.05).
Attitudes and amount of practice during adaptability treadmill training

Figure 7.3 Attitude towards adaptability treadmill training (AT, n=18), conventional treadmill training (CT, n=17) and usual physical therapy (UPT, n=21). X – median, shaded bars – range. Kruskal-Wallis test statistics are presented on the right.

Table 7.2 Perceived discomfort during and after training sessions.

<table>
<thead>
<tr>
<th></th>
<th>AT (n=18)</th>
<th>CT (n=17)</th>
<th>UPT (n=21)</th>
<th>p value*</th>
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<tbody>
<tr>
<td>Perceived discomfort during training sessions</td>
<td></td>
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<tr>
<td>No, n (%)</td>
<td>7 (38.9)</td>
<td>7 (41.2)</td>
<td>12 (57.1)</td>
<td>0.501</td>
</tr>
<tr>
<td>Yes once, n (%)</td>
<td>2 (11.1)</td>
<td>4 (23.5)</td>
<td>2 (9.5)</td>
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<tr>
<td>Yes frequently, n (%)</td>
<td>9 (50.0)</td>
<td>6 (35.3)</td>
<td>7 (33.3)</td>
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<tr>
<td>Perceived discomfort after training sessions</td>
<td></td>
<td></td>
<td></td>
<td>0.247</td>
</tr>
<tr>
<td>No, n (%)</td>
<td>9 (50.0)</td>
<td>13 (76.5)</td>
<td>13 (61.9)</td>
<td></td>
</tr>
<tr>
<td>Yes once, n (%)</td>
<td>1 (5.6)</td>
<td>1 (5.9)</td>
<td>0 (0.0)</td>
<td></td>
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<tr>
<td>Yes frequently, n (%)</td>
<td>8 (44.4)</td>
<td>3 (17.6)</td>
<td>8 (38.1)</td>
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</table>

Abbreviations: AT – adaptability treadmill, CT – conventional treadmill, UPT – usual physical therapy. *p values were obtained by Kruskal-Wallis tests.
Discomfort during and after training sessions mainly comprised muscle soreness, painful joints (predominantly knees, hips, shoulders), fatigue and shortness of breath. The number of participants perceiving discomfort during and after training sessions is reported in Table 7.2 for the AT, CT and UPT groups and was not significantly different among the three groups (both $\chi^2(2)<2.779$, $p>0.247$). Half of the participants in the AT and CT groups who perceived one-time discomfort (i.e., 1 out of 2 and 2 out of 4 participants, respectively) and two-thirds of the participants who perceived frequent discomfort (i.e., 6 out of 9 and 4 out of 6 participants, respectively) during training sessions also experienced this during the sessions of usual physical therapy they received. In addition, frequent discomfort after AT and CT training was also experienced after usual physical therapy in respectively half (i.e., 4 out of 8) and two-thirds (i.e., 2 out of 3) of the cases.

**Amount of walking practice**

The number of performed steps and the actual walking duration per training session are presented in Figure 7.4 for the AT, CT and AC groups. Significant group differences were observed for the number of performed steps per training session ($\chi^2(2)=17.957$, $p<0.001$). Post hoc analyses revealed that participants in the AT and CT groups performed significantly more steps per training session on the treadmill than the AC group per session of usual physical therapy (both $U\leq40.0$, $p<0.001$, $r>0.627$, AT: 803.4 [426.1-1,174.5], CT: 847.8 [416.8-1,415.5], UPT: 368.0 [135.0-1,179.5]). Walking duration per training session was not significantly different among groups ($F(2,49)=0.255$, $p=0.776$, $\eta^2=0.010$).

![Figure 7.4](image.png)  
**Figure 7.4** Amount of walking practice during adaptability treadmill (AT, $n=19$), conventional treadmill (CT, $n=17$) and additional comparison (AC, $n=16$) training sessions. Asterisks denote a significant difference among groups as demonstrated with post hoc Mann-Whitney $U$ tests, **$p<0.001$.**
Discussing

The present study examined older adults’ attitudes towards adaptability treadmill training, conventional treadmill training and usual physical therapy as well as the amounts of walking practice evoked by these three forms of training. In contrast to our hypothesis, no attitude differences were observed between training groups. All groups rated their training as useful, motivating, fun, challenging and enjoyable (Figure 7.3). The amount of walking practice was greater in adaptability treadmill training sessions and conventional treadmill training sessions than in usual treadmill training with more than twice as many steps performed per training session for both treadmill training groups.

Attitude towards training

Although Heeren et al. [49] and Fonteyn et al. [50] recently reported that adaptability treadmill training was well appreciated by people with respectively stroke and cerebellar degeneration, the present study was, to our knowledge, the first to specifically investigate the attitude of older adults (with a fall-related hip fracture) towards adaptability treadmill training. In general, few studies have focused on older adults’ attitude towards treadmill-based interventions. Marsh et al. [51] examined older adults’ attitude towards treadmill walking relative to group-based overground walking around an indoor track and found positive attitudes towards both forms of training. Participants in the treadmill walking group of that study rated their attitude and level of enjoyment with respectively 81.4 and 75.1 on a scale from 0 to 100, which is comparable to what was found in the present study (Figure 7.3). More studies reported on the perceived levels of enjoyment during advanced and interactive video gaming in older adults. A recent systematic review by Pietrzak et al. [19], for example, reported that older adults enjoyed the video games and were motivated to play. However, many of the cited studies introduced a selection bias by including self-selected participants for the video gaming intervention [17, 52, 53], which was prevented in the present study by adopting a randomized controlled trial design. In addition, Graves et al. [24] showed high enjoyment rates during balance and aerobic Wii Fit activities as well as during brisk treadmill walking in older adults (all ≥ 70.3 at the 100-point physical activity enjoyment scale), which is in line with the present study showing high enjoyment rates for all three forms of training (Figure 7.3). In fact, the present study showed overall positive attitudes towards all three forms of training (Figure 7.3). Older
adults thus seem to be open to a variety of training forms including those involving new, advanced technologies.

Participants in all three groups tolerated the interventions well and the dropout rate in the present study (Figure 7.1) is in line with that in previous studies on comparable elderly populations [46, 54]. Participants reported only mild discomfort during and after training sessions, without exhibiting any serious adverse events related to the training. The participants in the adaptability treadmill training group rated visually guided stepping with stepping targets changing to obstacles and the interactive walking adaptability game most frequently as “difficult”. Interestingly, these are the two exercises that particularly require cognitive decision making and online step adjustments in order to interact adequately with the projected visual context and thus rely predominantly on executive function [55], a skill reduced in our participants as indicated by their low scores on the Trail Making Test (Table 7.1, cf. [56]). Fortunately, executive function might improve after training [16], which is important since reductions in this skill have been associated with gait impairments, reduced obstacle avoidance ability and falling [55, 57, 58].

**Amount of walking practice**

As expected, our results indicate that treadmill training results in a greater amount of walking practice than usual physical therapy in older adults with a fall-related hip fracture. This is in line with the small number of studies that quantitatively compared the number of steps performed during treadmill training with overground gait training, reporting three to ten times as many steps for treadmill training compared to conventional physical therapy or overground walking adaptability training in persons with total hip arthroplasty [29], incomplete spinal cord injury [34] and stroke [27, 32, 35]. The present study further indicates that the greater number of steps performed during conventional treadmill training is preserved when projecting visual context on the belt’s surface, as evidenced by the absence of a significant difference in the number of steps per training session between adaptability treadmill training and conventional treadmill training (Figure 7.4). In addition to targeting the ability to make step adjustments and its associated attentional demands as important factors for safe community ambulation [59], adaptability treadmill training thus also allows for a great amount of walking practice, which is generally regarded as an important factor for effective rehabilitation [13, 14, 27].
Although the sessions of usual physical therapy had variable content and consisted not solely of walking, the time spent walking per session of usual physical therapy was not significantly different from the treadmill-based training sessions (Figure 7.4), indicating that time spent walking did not explain the lower number of steps performed during usual physical therapy. The lower number of steps during sessions of usual physical therapy can be explained by a lower average walking speed during these sessions due to turning, stopping and the use of a walking aid, which were eliminated during treadmill walking on a set speed [28, 30]. Note that the number of performed steps per session of usual physical therapy was estimated from a single session of usual physical therapy in an additional comparison group. This group was representative of the participants included in the six-week intervention trial. Both groups showed comparable age and height, and exhibited various comorbidities, albeit with some subtle differences (Table 7.1). Furthermore, FAC scores were not all that different for both groups considering the entire intervention period. It is therefore unlikely that the difference in amount of walking practice between usual physical therapy and both treadmill training interventions was caused by a poorer walking function of the additional comparison group.

Limitations
The questionnaire used to evaluate attitude towards training was specifically developed to reflect the aim of the study and its interventions, and was based on previous questionnaires on attitude towards training [24, 51]. Nevertheless, the questionnaire used in the present study has not been used previously and its validity and reliability have not been established. Another limitation was that the questionnaire was susceptible to a gratitude bias, meaning that participants might have been reluctant to express critical comments about the received intervention [60]. It is unfortunate in that respect that the present study did not evaluate the change in attitude towards training from pre to post intervention. However, the distribution of the scores showed that participants were not reluctant to give less positive rates. Participants in both treadmill training groups rated their initial reserve with the assigned treadmill intervention with a median score of 6.0 (on a scale from 1 [low] to 10 [high]), which indicates that participants were initially moderately reserved with the training. In fact, additional analysis showed that the scores for initial reserve were significantly less favorable than the scores of all other questions (Friedman test: $\chi^2(7) > 20.569$, $p < 0.003$ for both treadmill groups, planned post hoc Wilcoxon signed-rank tests: all $z < -2.937$, $p < 0.002$ and all
$z<-2.241, \ p<0.025$ for adaptability and conventional treadmill training, respectively), including those evaluating the perceived relevance for older adults and the recommendation to peers after completing the assigned training. This supports our finding that participants were positive towards all three forms of training and may indicate that the participants receiving adaptability and conventional treadmill training positively changed their attitude towards both forms of training in the course of the intervention period.

**Conclusions**

The results of the present study indicate that adaptability treadmill training, conventional treadmill training and usual physical therapy are all well received by older adults recovering from a fall-related hip fracture. In addition, both forms of treadmill training may result in greater amounts of walking practice per training session than usual physical therapy in older adults with a fall-related hip fracture. No differences were observed between the two forms of treadmill training, which indicates that projecting visual context on the belt’s surface with the aim to enhance the task-specificity of treadmill training does not lead to a different amount of walking practice than conventional treadmill training. Although a great amount of practice is deemed important for effective rehabilitation [13, 14, 27], future studies should not only test this assumption but also compare the three forms of training on their efficacy for improving walking ability and fall incidence in older adults (see [15] for an example).
Acknowledgements

The authors thank Susan Arendse, Els Nijenhuis, Jan Visschedijk and Anne van Reemst from PW Janssen, Zorggroep Solis, Deventer for supporting patient recruitment and data collection and Nicole Goedhart and Francien Meijer from Vrije Universiteit Amsterdam for collecting the data in the additional comparison group.

Competing interests

MR and PJB are inventors of rehabilitation treadmills that include visual context for foot placement (cf. [12]). Vrije Universiteit Amsterdam granted this idea exclusively to ForceLink (Culemborg, the Netherlands, now part of Motekforce Link, Amsterdam, the Netherlands), an industrial partner of Vrije Universiteit Amsterdam. ForceLink is manufacturer of the C-Mill and assignee of a patent for rehabilitation treadmills with visual context for foot placement, with MR and PJB listed as inventors. Vrije Universiteit Amsterdam received patent revenues, and transferred part of these revenues to spend them freely for their research endeavors. Vrije Universiteit Amsterdam used these revenues to finance a research project on the effectiveness of C-Mill training. The present study is part of that research project. ForceLink had no influence on the project content, the interpretation of the results, the final conclusions and their publication. MR and PJB did not receive reimbursements, fees, funding or salary from ForceLink, nor did or do they benefit personally from patent revenues.

References


Attitudes and amount of practice during adaptability treadmill training

Additional file 1.

Purpose-designed questionnaire used to evaluate participants’ attitude towards adaptability treadmill training, conventional treadmill training and usual physical therapy. The used questionnaire is in Dutch, an English translation is provided.

**VRAGENLIJST: EVALUATIE C-MILL THERAPIE**

Deze vragenlijst gaat over de C-Mill therapie die u de afgelopen 6 weken heeft gehad. Wij willen u vragen onderstaande vragen te beantwoorden.


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8. Was u in eerste instantie terughoudend over de C-Mill therapie? Kies het vakje (cijfer) dat het beste past.


10. Zou u anderen deze vorm van therapie aanraden? Kies het vakje (cijfer) dat het beste past.

11. Welk onderdeel van de training heeft u als makkelijk ervaren? (meerder antwoorden zijn mogelijk)

   - Het ontwijken van obstakels
   - Het volgen van een looppatroon met variatie
   - Het volgen van een looppatroon met variatie en paarse staptegels.
   - Het versnellen en vertragen van het lopen
   - Het eindspel
12. Welk onderdeel van de training heeft u als moeilijk ervaren? (meerdere antwoorden zijn mogelijk)
- Het ontwijken van obstakels
- Het volgen van een looppatroon met variatie
- Het volgen van een looppatroon met variatie en paarse staptegels.
- Het versnellen en vertragen van het lopen
- Het eindspel

13. Heeft u tijdens een of meerdere therapiesessies op de C-Mill klachten gehad (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid)?
- Ja, meerdere keren
- Ja, 1 keer
- Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk):
- Ernstige vermoeidheid
- Spierpijn
- Duizeligheid
- Misselijkheid
- Kortademigheid
- Gewrichtsklachten, namelijk __________________________________
- Anders, namelijk __________________________________________

Had u deze klachten ook tijdens de andere therapiesessies (in de oefenzaal en op de afdeling)?
- Ja
- Nee

14. Heeft u eine of meerdere therapiesessies op de C-Mill klachten gehad (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid)?
- Ja, meerdere keren
- Ja, 1 keer
- Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk):
- Ernstige vermoeidheid
- Spierpijn
- Duizeligheid
- Misselijkheid
- Kortademigheid
- Gewrichtsklachten, namelijk __________________________________
- Anders, namelijk __________________________________________

Had u deze klachten ook tijdens de andere therapiesessies (in de oefenzaal en op de afdeling)?
- Ja
- Nee
VRAGENLIJST: EVALUATIE LOOPBAND THERAPIE

Deze vragenlijst gaat over de loopband therapie die u de afgelopen 6 weken heeft gehad. Wij willen u vragen onderstaande vragen te beantwoorden.

1. Heeft u de loopband therapie als nuttig ervaren? Kies het vakje (cijfer) dat het beste past.

   1  2  3  4  5  6  7  8  9  10

   NEE  JA

2. Vond u de loopband therapie motiverend? Kies het vakje (cijfer) dat het beste past.

   1  2  3  4  5  6  7  8  9  10

   NEE  JA


   1  2  3  4  5  6  7  8  9  10

   NEE  JA

4. Vond u de loopband therapie uitdagend? Kies het vakje (cijfer) dat het beste past.

   1  2  3  4  5  6  7  8  9  10

   NEE  JA

5. Heeft u de loopband therapie als plezierig ervaren? Kies het vakje (cijfer) dat het beste past.

   1  2  3  4  5  6  7  8  9  10

   NEE  JA

6. Vond u de duur van de therapisessies op de loopband goed? Kies het vakje (cijfer) dat het beste past.

   1  2  3  4  5  6  7  8  9  10

   NEE  JA
7. Vond u de frequentie van de loopband therapie goed? Kies het vakje (cijfer) dat het beste past.

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8. Was u in eerste instantie terughoudend over de loopband therapie? Kies het vakje (cijfer) dat het beste past.

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10. Zou u anderen deze vorm van therapie aanraden? Kies het vakje (cijfer) dat het beste past.

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11. Heeft u tijdens een of meerdere therapiesessies op de loopband klachten gehad (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid)?

- Ja, meerdere keren
- Ja, 1 keer
- Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk).

- Ernstige vermoeidheid
- Spierpijn
- Duizeligheid
- Misselijkheid
- Kortademigheid
- Gewrichtsklachten, namelijk ____________________________
- Anders, namelijk ____________________________
Had u deze klachten ook tijdens de andere therapiesessies (in de oefenzaal en op de afdeling)?

☐ Ja
☐ Nee

12. Heeft u NA een of meerdere therapiesessies op de loopband klachten (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid) gehad?

☐ Ja, meerdere keren
☐ Ja, 1 keer
☐ Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk).

☐ Ernstige vermoeidheid
☐ Spierpijn
☐ Duizeligheid
☐ Misselijkheid
☐ Kortademigheid
☐ Gewrichtsklachten, namelijk ________________________________
☐ Anders, namelijk ________________________________

Had u deze klachten ook na de andere therapiesessies (in de oefenzaal en op de afdeling)?

☐ Ja
☐ Nee
Attitudes and amount of practice during adaptability treadmill training

**VRAGENLIJST: EVALUATIE THERAPIE**

Deze vragenlijst gaat over de therapie die u de afgelopen 6 weken heeft gehad. Wij willen u vragen onderstaande vragen te beantwoorden.

1. Heeft u de therapie als nuttig ervaren? Kies het vakje (cijfer) dat het beste past.

   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
---|---|---|---|---|---|---|---|---|---|----|
   | NEE | JA |

2. Vond u de therapie motiverend? Kies het vakje (cijfer) dat het beste past.

   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
---|---|---|---|---|---|---|---|---|---|----|
   | NEE | JA |


   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
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   | NEE | JA |


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5. Heeft u de therapie als plezierig ervaren? Kies het vakje (cijfer) dat het beste past.

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8. Heeft u **TIJDENS** een of meerdere therapiesessies klachten gehad (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid)?

- [ ] Ja, meerdere keren
- [ ] Ja, 1 keer
- [ ] Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk):

- [ ] Ernstige vermoeidheid
- [ ] Spierpijn
- [ ] Duizeligheid
- [ ] Misselijkheid
- [ ] Kortademigheid
- [ ] Gewrichtsklachten, namelijk ____________________________
- [ ] Anders, namelijk ____________________________

9. Heeft u **NA** een of meerdere therapiesessies klachten gehad (bv. ernstige vermoeidheid, spierpijn, duizeligheid, kortademigheid)?

- [ ] Ja, meerdere keren
- [ ] Ja, 1 keer
- [ ] Nee

Zo ja, waar bestonden deze klachten uit (meerdere antwoorden zijn mogelijk):

- [ ] Ernstige vermoeidheid
- [ ] Spierpijn
- [ ] Duizeligheid
- [ ] Misselijkheid
- [ ] Kortademigheid
- [ ] Gewrichtsklachten, namelijk ____________________________
- [ ] Anders, namelijk ____________________________
Attitudes and amount of practice during adaptability treadmill training

Questionnaire: EVALUATION ADAPTABILITY TREADMILL TRAINING

This questionnaire concerns the adaptability treadmill training that you have received in the last 6 weeks. We ask you to answer the following questions.

1. Did you perceive the adaptability treadmill training as useful? Select the box (mark) that fits best.

   NO | YES

2. Did you perceive the adaptability treadmill training as motivating? Select the box (mark) that fits best.

   NO | YES

3. Did you perceive the adaptability treadmill training as fun? Select the box (mark) that fits best.

   NO | YES

4. Did you perceive the adaptability treadmill training as challenging? Select the box (mark) that fits best.

   NO | YES

5. Did you perceive the adaptability treadmill training as enjoyable? Select the box (mark) that fits best.

   NO | YES

6. Do you think the duration of the therapy sessions on the adaptability treadmill was good? Select the box (mark) that fits best.

   NO | YES
7. Do you think the frequency of the therapy sessions on the adaptability treadmill was good? Select the box (mark) that fits best.

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8. Were you initially reserved towards the adaptability treadmill training? Select the box (mark) that fits best.

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9. Do you consider this type of therapy relevant for peers? Select the box (mark) that fits best.

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10. Would you recommend this type of therapy to others? Select the box (mark) that fits best.

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11. Which part of the training did you perceive as easy? (Multiple answers are possible)

- Obstacle avoidance
- Visually guided stepping to irregularly spaced stepping targets
- Visually guided stepping to irregularly spaced stepping targets with targets occasionally and suddenly changing to obstacles
- Speeding up and slowing down
- Gait adaptability games

12. Which part of the training did you perceive as difficult? (Multiple answers are possible)

- Obstacle avoidance
- Visually guided stepping to irregularly spaced stepping targets
- Visually guided stepping to irregularly spaced stepping targets with targets occasionally and suddenly changing to obstacles
- Speeding up and slowing down
- Gait adaptability games
Attitudes and amount of practice during adaptability treadmill training

13. Did you perceive discomfort(s) **DURING** one or more adaptability treadmill training sessions (e.g., severe fatigue, muscle soreness, dizziness, shortness of breath)?
   - Yes, multiple times
   - Yes, once
   - No

If so, what were these discomforts *(multiple answers are possible)*:
   - Severe fatigue
   - Muscle soreness
   - Dizziness
   - Nausea
   - Shortness of breath
   - Painful joints, namely ________________________________
   - Other, namely ________________________________

Did you perceive these discomforts also **during** the other therapy sessions (in the exercise room and on the ward)? b
   - Yes
   - No

14. Did you perceive discomfort(s) **AFTER** one or more adaptability treadmill training sessions (e.g., severe fatigue, muscle soreness, dizziness, shortness of breath)?
   - Yes, multiple times
   - Yes, once
   - No

If so, what were these discomforts *(multiple answers are possible)*:
   - Severe fatigue
   - Muscle soreness
   - Dizziness
   - Nausea
   - Shortness of breath
   - Painful joints, namely ________________________________
   - Other, namely ________________________________

Did you perceive these discomforts also **after** the other therapy sessions (in the exercise room and on the ward)? b
   - Yes
   - No

*a The questionnaire was about conventional treadmill training sessions and usual physical therapy sessions for respectively the conventional treadmill training group and the usual physical therapy group. b This (part of the) question was not included in the questionnaire for the usual physical therapy group. c This question was only included in the questionnaire for the adaptability treadmill training group*
Additional file 2

Video of C-Mill walking adaptability exercises. C-Mill walking adaptability exercises include visually guided stepping to a regular or irregular sequence of stepping targets, obstacle avoidance, speeding up and slowing down, and all of the above in a functional and interactive walking adaptability game. This video is available at https://youtu.be/5SLQp4hAVFk.