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The effect of abduction bracing on preventing movements that pose a risk for hip dislocation: A randomized, crossover, single-center trial in non-disabled individuals

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Full length article

The effect of abduction bracing on preventing movements that pose a risk for hip dislocation: A randomized, crossover, single-center trial in non-disabled individuals

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ABSTRACT

Background: Hip dislocation after total hip arthroplasty (THA) is a major complication which restricts the patient's mobility and may lead to recurrent displacements. Rigid and non-rigid hip abduction braces are widely used as a non-operative method to prevent movement patterns that can pose a dislocation risk. However, their effectiveness remains controversial, and the patients' compliance with these braces is not clearly established in the scientific literature.

Research question: The primary objective of this study was to examine the effects of rigid and non-rigid braces on spatiotemporal and kinematic parameters in non-disabled individuals while performing different activities of daily living (ADL). The secondary aim of this research work was to evaluate the participants' perspective of the braces.

Methods: In this single-center, randomized, crossover trial, four subjects were analyzed. Three-dimensional gait analysis with a rigid, non-rigid, and without a brace in randomized order was conducted using a biomechanical cluster model consisting of retro-reflective markers and an optoelectronic motion capture system as the subjects performed 4 different ADL tasks; straight walking, figure-eight movement, squatting and picking up an object from the ground, and putting on shoes. Hip flexion, adduction, internal/external rotation angles, and spatiotemporal parameters were calculated. The participants' perspective of the braces was evaluated through a questionnaire.

Results: Analysis of spatiotemporal variables during straight walking revealed no significant differences between the unbraced and braced conditions. Furthermore, no significant kinematic effects of braces provision were found comparing the peak hip angles during the selected ADL tasks. However, noteworthy median peak differences were found on hip flexion with both braces compared to the unbraced condition, and adduction or exorotation between the unbraced and rigid braced condition. From the participants' perspective of the braces, we conclude that although the rigid brace was more cumbersome compared to the non-rigid brace, it can be more effective in preventing movements that pose a dislocation risk.

Keywords: Total hip arthroplasty; Dislocation; Abduction brace; Hip angles; Gait analysis; Randomized crossover trial

Trial registration number: NTR6883

1. Introduction

Osteoarthritis (OA) is a degenerative joint disease and one of the most common musculoskeletal conditions in the developed countries [1]. OA results in functional limitations and difficulties in performing the major activities of daily living (ADL). Total hip arthroplasty (THA) is an effective procedure that is performed by orthopedic surgeons in order to relieve the pain and restore the function of the hip joint, hence improving the quality of life of patients affected by severe OA [2, 3]. However, hip dislocation following THA is a frequent and costly complication that may not only restrict the mobility and cause discomfort or mental stress to the

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patient but also might lead to recurrent displacements [4].

Literature [5-7] indicates that surgical approach, implant design, and positioning of prosthetic components are important variables that may influence the dislocation rates. Postoperative factors and restrictions are also a vital aspect of post-THA and these can be divided into three main categories; movement restrictions, daily life functional restrictions, and use of assistive devices [8]. Movement restrictions deal with limiting excessive hip flexion (<90 degrees), rotation (<45 degrees), and adduction or a combination of them. These movement positions theoretically increase the risk of a dislocation, especially in the postoperative period before healing of the capsular and tissue elements around the prosthetic hip [7-9].

To prevent recurrent hip dislocations, rigid and non-rigid hip abduction braces are widely used as a non-operative treatment in order to restrict risky movements that can cause a dislocation. Although these braces are frequently prescribed in clinical care, there is little evidence to support their use for preventing hip displacements, and their effect is actually not well studied in the scientific literature. Based on a literature review [10], it has been shown that applying a brace during the early postoperative period may be effective and prevents initial hip dislocation by helping the patients to recognize careless provocative positions. However, several studies [11-16] suggest that braces are not able to prevent hip displacements, and therefore the dislocation rates do not decrease. One limitation of these studies is that the patients' compliance with these braces is not clearly recorded by the researchers, and consequently, their effectiveness remains controversial as it is unspecified whether the lack of effect is the result of an ineffective brace or non-compliant users.

The primary objective of this study was to investigate the effects of rigid and non-rigid hip brace provision on spatiotemporal and kinematic parameters in non-disabled individuals while performing ADL tasks which can pose a displacement risk. The secondary purpose of this study was to examine the participants' perspective with respect to both braces through a structured questionnaire. It was hypothesized that the rigid brace minimizes the comfortability of the subjects during the execution of the selected ADL tasks, but it is likely to prevent more risky movements compared to the non-rigid brace by reducing the ROM of the hip joint because of the sturdiness of its material.

2. Methods

2.1. Subjects

In this single-center, randomized, crossover study, 3 males and 1 female subject were recruited through advertising and public invitations from September 2017 to July 2018. The study was approved by the local ethics committee, registered in "the Netherlands Trial Register", number NTR6883, and followed the CONSORT guidelines. Eligible subjects were aged between 40 and 70 years old and they were also able to be physically active (low-intensity) for a time period of three hours. Individuals were excluded from the study if they reported any musculoskeletal problems influencing walking ability and ROM of the hip, or a joint replacement surgery of one of the joints of the lower extremities. Participants without a basic comprehension of English or Dutch instructions were also excluded from the study. All subjects provided written informed consent.

2.2. Randomization

Simple randomization was performed by means of a computer-generated schedule, and specifically using the Excel software to determine the order of the examined conditions. A list of three random numbers was generated and these numbers were linked to one of the conditions; wearing no brace, wearing a non-rigid brace, and wearing a rigid brace. The numbers were arranged in ascending order, and this determined the sequence in which the conditions were measured. The leg on which the braces were worn (dominant/non-dominant) was also randomized. Both the participants and the researchers could not be blinded for allocation.

2.3. Hip braces provision

Subjects were provided with two types of hip braces which differ in the sturdiness of the used materials: 1) the Rebound Hip brace (Össur Europe, Eindhoven, the Netherlands) (Fig.1) which uses non-rigid materials to improve patient comfort and compliance; and 2) the Newport 4 hip brace (Basko Healthcare, Zaandam, the Netherlands) (Fig.1) which consists of rigid materials to increase control of the movements around the hip. Fitting of braces was performed by a licensed orthotist from the Roessingh, Rehabilitation Technique in Enschede, the Netherlands.

Fig. 1. Two types of hip braces used in the study
This figure shows the two types of hip braces used in the study. From left to right: 1) the non-rigid Rebound hip brace incorporating a hip plate with flexion/extension stops, an adjustable hinge for abduction/adduction control, a standard hinge applying constant abduction force, and an additional strap attached to both the pelvic and thigh straps for rotation restriction; 2) the rigid Newport 4 hip brace consisting of a pelvic, thigh, and a hip joint component along with a hinge with multiple distal bars providing flexion/extension stops and abduction/adduction adjustment.

2.4. Testing protocol

The testing protocol consisted of four different ADL tasks for each of the aforementioned conditions; straight walking, walking in an eight-figure, squatting and picking up an object from the ground, and putting on shoes. During the straight-walking trials, the participants were asked to walk back and forth at self-selected speeds over a 10-meter walkway until 15 valid strides have been made. This task was included to investigate the effect of the braces on the spatiotemporal parameters. During walking in an eight-figure, the subjects were asked to follow a figure-eight movement around two cones placed 5 meters apart in such a way that the leg on which the brace was worn made the inside turn. A figure of eight was chosen due to adduction and rotation required while making turns. In terms of squatting, the subjects were asked to stand upright (reference position) and then squat in order to pick up an object between their feet. The last task included putting on shoes, during which the participants were first asked to sit in a chair and then cross their legs so that the left/right knee to rest on the top of the right/left knee and grasp their left/right foot in both hands. Previous studies have shown that squatting and putting on shoes are both highly risky activities which should be avoided for at least one year after THA [6, 17, 18], as they can cause excessive hip flexion [17, 18], external rotation and adduction [19], respectively. A total of 6 successful trials per task were recorded for subsequent analysis.

2.5. Data collection and gait analysis

At inclusion, basic demographic characteristics for each individual were recorded. The spatiotemporal and kinematic data were collected using a six-camera Vicon MX13+ motion analysis system (Vicon Motion Systems, Oxford, UK), operating at 100Hz to record three-dimensional (3D) marker trajectories. A modified marker set was used consisting of a combination of eight 25mm reflective markers, and five marker clusters incorporating four 12mm markers each one. The retro-reflective markers were placed bilaterally, directly on the skin and shoes of the knee, ankle, and toe and heel, respectively. The marker clusters were attached to the pelvis and bilaterally to the lateral thigh and tibia body segments (Fig. 2). During the conditions of wearing a brace, the pelvic cluster was attached over the pelvic strap, while the thigh clusters were placed onto the spring rod of both braces just below the upper thigh cuff (Fig. 2). This marker system is a modification of the Plug-In gait lower body model as previously published by the Vicon plug-in gait reference guide [20]. All markers were attached using double-sided tape.

Data processing was performed using the lower-body Plug-In gait model from the Vicon Nexus software. Identification of initial contact and toe-off moments was done manually, and a custom Matlab program (MathWorks, Natick, Massachusetts) was developed to extract the spatiotemporal and kinematic variables of interest for each subject.

Fig. 2. Marker setup for the biomechanical gait analysis during the three examined conditions. From left to right: 1) Marker set without wearing a hip brace, 2) with the Rebound hip brace, and 3) the Newport 4 hip brace.

2.6. Outcome measures

The primary outcome measures of the study were the sagittal (flexion), frontal (adduction), and transverse (endorotation/exorotation) hip movement during the execution of the aforementioned ADL tasks. For the activity of walking in an eight-figure, peak hip angles were calculated during the inside turn moments. Besides, spatiotemporal parameters were calculated. The participants' perspective of the braces was assessed through a structured questionnaire which was administered in person after the completion of the measurements (see supplemental material).

2.7. Statistical analysis

A priori power calculation for the sample size required was not performed since no similar studies investigating the biomechanical effects of such hip braces on prevention of hip displacement were found in the literature. Therefore, the sample size was based on the notion that the effect of the braces first needs to be examined regarding the restriction of the movements that can pose a dislocation risk, and then, taking into account the results of this preliminary study a larger population can be justified. The SPSS version 19.0 (IBM Japan Ltd.) was used for statistical analysis. To examine the effects of braces provision, the Wilcoxon signed-ranked test was conducted in order to compare either the spatiotemporal or the kinematic variables in the measurements with and without the braces. To reduce the probability of a type II error due to multiple comparisons, the Holm-Bonferroni method was used for data correction. The significance level was set at $p<.05$.

3. Results

3.1. Participants' characteristics

In total, 4 non-disabled individuals consented to participate and were included in this study. All the participants completed the measurement sessions and were included in the data analysis. Table 1 shows the basic individuals' characteristics recorded at inclusion. The participants' flow through the study is detailed in Fig. A.1 (see supplemental material).

Table 1. Participants' characteristics at inclusion

Variables	Total (n = 4)
Sex (male/female)	3/1
Age (years)	49.50 (41 - 67)
Height (cm)	174.75 (169 - 190)
Weight (kg)	72.5 (68.2 - 81)

Sex is presented as counts.
Age, height, and weight are presented as median (range).

3.2. Spatiotemporal gait characteristics

Comparison of the spatiotemporal gait parameters between the conditions of without wearing a brace, wearing the Rebound and the Newport 4 Hip Brace revealed no significant differences during straight walking. A post-hoc analysis was also performed to correct data due to multiple tests, but still, no significant differences in both spatial and timing gait variables were found from the comparison of the unbraced and braced conditions. Spatiotemporal gait characteristics of the individuals for each of the three examined conditions are summarized in Table 2.

3.3. Kinematic effects of hip braces provision

The kinematic effects of hip braces provision are analytically shown in Table 3 and visually presented in Fig. 3. No significant kinematic effects of hip braces provision were found comparing the peak hip angles between the conditions of without wearing a brace, wearing the Rebound hip brace and the Newport 4 hip brace. There were no significant differences between the three examined conditions in peak angles for hip flexion during squatting and picking up an object from the ground $(0.068 \leq p \leq 0.273)$. Additionally, no differences were found in hip flexion, adduction, and exorotation angles between the three conditions during the task of putting on shoes $(0.068 \leq p \leq 0.204; 0.144 \leq p \leq 0.715; 0.465 \leq p \leq 1.000)$. The analysis of the peak hip adduction and endorotation angles between the measured conditions during the inside turn of the figure-eight movement showed no statistically significant effects of the provided hip braces $(0.068 \leq p \leq 0.204; 0.432 \leq p \leq 0.465)$. A post-hoc analysis using the Holm-Bonferroni method was conducted for data correction to account for multiple comparisons, but there were still no significant differences between the tested conditions in peak angles for hip flexion, abduction/adduction and internal/external rotation while performing the aforementioned ADL tasks.

3.4. Participants' perspective of the hip braces

The participants' perspective of each hip brace was assessed through a structured questionnaire which was filled in by the subjects after the completion of the experiments. Most of the participants reported that the non-rigid brace was lightweight and easy to be adapted to their leg in contrast to the rigid brace which was cumbersome due to its materials and probably needed the support of an expert to be able to wear it. Furthermore, the majority of respondents indicated that they were able to complete all the tasks of the testing protocol wearing the non-rigid brace, expressing their satisfaction with the time it took to them to perform the selected activities. On the other hand, half of the individuals reported that they were not able to complete the tasks with the rigid brace. The results of the individuals' perspective of both hip braces are displayed in Fig. 4.

4. Discussion

The primary aim of this study was to investigate the spatiotemporal and kinematic effects of hip brace provision in non-disabled individuals while performing different ADL tasks.

Straight-walking trials presented no significant differences in the spatiotemporal parameters between the unbraced and braced conditions. These results are in accordance with the findings of Nerot et al. [21] who used a hip brace (Hip Unloader, Össur, Reykjavik, Iceland) and also reported no significant effects of brace provision on the spatiotemporal parameters, but they found a difference in gait speed which was negligible. The median spatiotemporal variables with the rigid brace showed a slight decrease in gait speed, cadence, step length, step width, and stride length compared to both the unbraced and non-rigid braced condition. Regarding the median timing gait parameters, an increase of approximately 5.5% of the stride duration was found, comparing the rigid braced condition with both the unbraced and non-rigid braced condition. This difference in duration of the stride could be explained by the fact that the gait speed decreased. As a consequence, the stance duration also increased. Nonetheless, the swing duration as a percentage of the gait cycle slightly decreased, maybe because of the hardness of the brace's materials which restricts the ROM of the hip joint and thus reduces the time that the subjects are able to have their foot lifted for the swing.

Table 2. Spatiotemporal gait characteristics of the individuals during straight walking

Straight walking															
Variables	**Without Brace**		**Non-rigid Brace (Rebound Hip Brace)**		**Rigid Brace (Newport 4 Hip Brace)**		WB vs. NRB			WB vs. RB			NRB vs. RB		
							Median difference		P	**Median difference**		P	**Median difference**		P
Gait speed(self-selected)(m/s)	1.28	[1.07,1.54]	1.29	[1.02,1.53]	1.13	[0.92,1.31]	-0.10	[-0.05,0.02]	0.465	-0.19	[-0.23,-0.10]	**0.204**	-0.15	[-0.22,-0.09]	0.068
Cadence (steps/min)	108.57	[101.00,110.14]	108.85	[97.38,111.80]	102.72	[92.95,105.86]	0.27	[-3.66,1.70]	0.715	-5.85	[-8.11,-4.20]	**0.204**	-5.96	[-6.15,-4.37]	0.068
Step length (m)	0.72	[0.62,0.84]	0.70	[0.62,0.84]	0.65	[0.59,0.76]	-0.00	[-0.01,0.00]	0.273	-0.06	[-0.08,-0.03]	**0.204**	-0.05	[-0.08,-0.03]	0.068
Step width (m)	0.73	[0.63,0.85]	0.71	[0.63,0.85]	0.67	[0.60,0.78]	-0.00	[-0.01,0.00]	0.273	-0.05	[-0.07,-0.02]	**0.204**	-0.04	[-0.06,-0.02]	0.068
Stride length (m)	1.44	[1.23,1.69]	1.41	[1.24,1.68]	1.30	[1.18,1.52]	-0.01	[-0.02,0.01]	0.273	-0.13	[-0.17,-0.05]	**0.204**	-0.10	[-0.16,-0.06]	0.068
Stride duration (s)	1.10	[1.09,1.19]	1.10	[1.07,1.23]	1.16	[1.13,1.29]	-0.00	[-0.01,0.04]	0.715	0.06	[0.04,0.10]	**0.204**	0.06	[0.05,0.06]	0.068
Stance duration (% stride)	60.61	[57.47,62.27]	60.98	[56.76,62.74]	62.09	[59.05,64.75]	0.19	[-1.08,1.02]	1.000	0.73	[-0.30,5.10]	**0.819**	1.58	[-0.77,4.60]	0.273
Initial Double Stance (% stride)	10.51	[8.28,12.42]	10.45	[7.04,13.10]	11.69	[8.93,14.27]	-0.06	[-1.70,1.13]	0.715	0.04	[-0.89,4.52]	**1.000**	1.50	[-1.56,4.36]	0.465
Single Support (% stride)	39.39	[37.15,41.14]	39.30	[36.89,41.83]	38.32	[36.01,40.94]	0.20	[-1.20,1.34]	0.715	0.63	[-4.27,1.21]	0.715	-0.63	[-3.57,1.45]	**1.000**
Terminal Double Stance (% stride)	10.67	[8.07,12.68]	11.22	[7.88,12.75]	12.08	[9.16,14.46]	-0.13	[-0.71,1.28]	1.000	0.05	[-0.60,4.83]	0.715	0.70	[-0.66,3.81]	**0.819**
Swing duration (% stride)	39.38	[37.72,42.52]	39.01	[37.25,43.23]	37.90	[35.24,40.94]	-0.19	[-1.02,1.08]	1.000	-0.73	[-5.10,0.30]	**0.819**	-1.58	[-4.60,0.77]	0.273

Data are presented as median [interquartile range]. Bold figures indicate the asymptotic significance after Holm-Bonferroni correction.
Abbreviations: WB: Without Brace; NRB: Non-rigid Brace; RB: Rigid brace

Table 3. Results of kinematic variables for the three examined conditions during squatting, putting on shoes, and figure-8 movement

Variables	**Without Brace**		**Non-rigid Brace (Rebound Hip Brace)**		**Rigid Brace (Newport 4 Hip Brace)**		WB vs. NRB			WB vs. RB			NRB vs. RB		
							Median difference		P	**Median difference**		P	**Median difference**		P
Hip Kinematics															
Squatting and Picking up an object from the ground															
Peak Flexion (degrees)	102.54	[92.40,110.58]	64.79	[55.24,76.81]	75.61	[68.55,77.48]	36.23	[25.56,44.93]	**0.204**	26.11	[18.57,42.03]	0.068	-6.37	[-18.31,4.67]	0.273
Putting on shoes															
Peak Flexion (degrees)	104.88	[89.61,115.04]	65.54	[58.56,68.65]	72.27	[65.08,78.59]	36.64	[30.11,50.01]	**0.204**	33.18	[14.85,45.54]	0.068	-8.87	[-15.70,1.38]	0.144
Peak Adduction (degrees)	15.37	[8.01,23.73]	12.78	[6.95,18.62]	3.45	[2.25,6.92]	6.46	[-7.98,10.27]	0.715	9.86	[3.41,21.22]	**0.204**	9.78	[0.03,15.92]	0.144
Peak Exorotation (degrees)	12.80	[2.93,22.15]	9.99	[1.51,16.65]	7.91	[2.52,11.31]	5.64	[-9.79,13.88]	**1.000**	4.53	[-6.42,18.01]	0.465	0.86	[-7.11,12.66]	0.715
Figure-8 movement															
Peak Adduction (degrees)	9.51	[8.06,11.47]	8.92	[4.60,10.01]	4.79	[3.13,6.43]	0.58	[-1.94,6.86]	0.465	4.71	[2.06,7.90]	**0.204**	-2.85	[1.03,5.29]	0.068
Peak Endorotation (degrees)	10.42	[7.31,18.05]	16.40	[12.97,33.17]	18.49	[12.69,25.01]	-4.38	[-25.86,3.48]	0.465	-4.37	[-16.51,0.47]	**0.432**	0.97	[-3.97,9.34]	0.465

Data are presented as median [interquartile range]. Bold figures indicate the asymptotic significance after Holm-Bonferroni correction.

Abbreviations: WB: Without Brace; NRB: Non-rigid Brace; RB: Rigid brace.

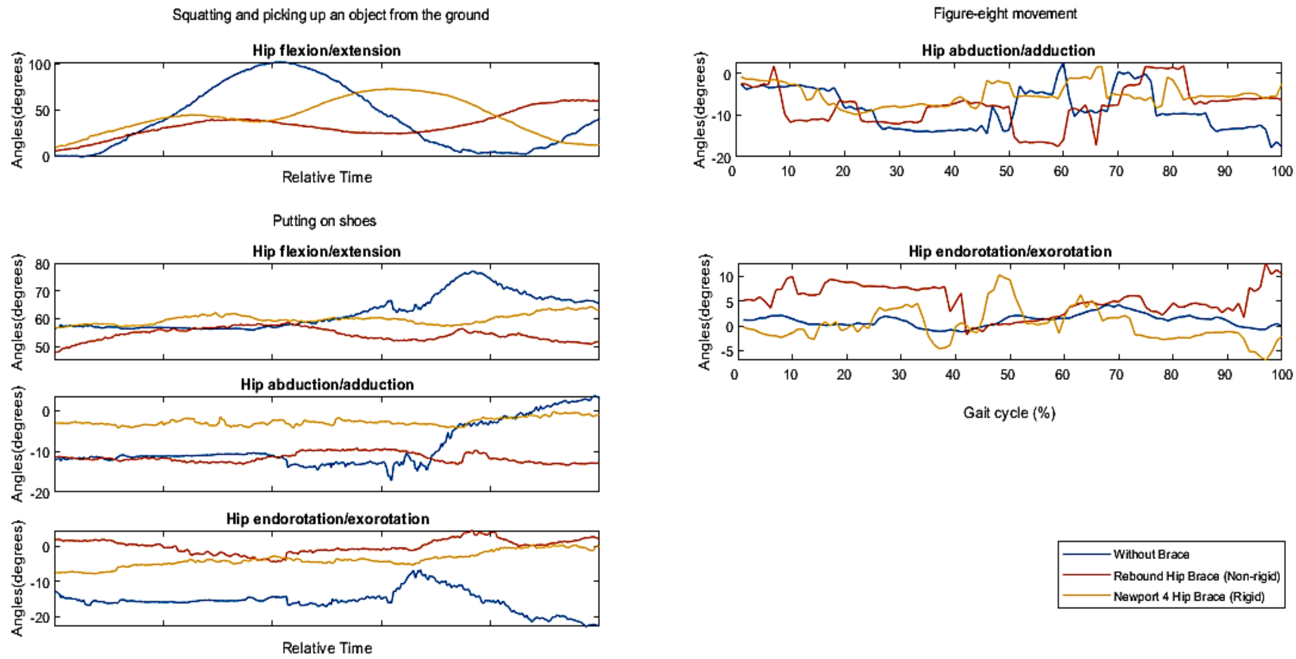

Fig. 3. Effects of braces provision on hip kinematics
This figure displays the mean hip kinematics (degrees) of the three experimental conditions for each of the three different examined ADL tasks. The data of the condition without a brace is shown as a solid blue line, the data of the condition with the Rebound hip brace is shown as a solid red line, and the data of the condition with the Newport 4 hip brace is shown as a solid yellow line.

The tasks of squatting and putting on shoes demonstrated no significant effects on sagittal hip movement compared to the unbraced and braced conditions. This means that the provision of hip braces did not affect the movement pattern around the hip in the sagittal plane. However, the median peak hip flexion angles (see Table 2) during the aforementioned activities indicate that both braces can effectively restrict excessive hip flexion (>90 degrees). Specifically, the analysis of median peak hip flexion angles during squatting showed that there was approximately 37% and 26% decrease in flexion when using the non-rigid and rigid brace (borderline significance; $p = 0.068$), respectively. Furthermore, there was a decrease of around 37.5%, from 104.88 to 65.54 degrees (non-rigid brace), and a decrease of 31%, from 104.88 to 72.27 degrees (rigid brace; borderline significance; $p = 0.068$), during putting on shoes. The findings of the unbraced condition are in line with previous studies [17-19, 22] which have reported squatting and putting on shoes as highly risky activities that can cause excessive hip flexion. In correspondence with the results of this study, Ishii et al. [10] used a hip brace of similar construction with the Newport 4 to investigate whether it can prevent the initial dislocation in the early postoperative period after THA, and they reported a peak hip flexion up to 70 degrees. Other studies [23, 24] have also examined the effect of rigid hip abduction braces on preventing hip dislocations, presenting 80 degrees of peak hip flexion. Nevertheless, the researchers do not clearly mention whether these braces are significantly effective in restricting the hip movement in the sagittal plane during highly demanding tasks, as performed in our study.

In the frontal plane, hip movement during putting on shoes and walking in an eight-figure revealed no significant differences of the peak hip adduction angles after braces provision. Though, provision of the rigid brace showed a decrease of the median peak hip adduction angles from 15.37 to 3.45 degrees (putting on shoes) and from 9.51 to 4.79 degrees (figure-eight) compared to the unbraced condition. Hyodo et al. [19] measured the peak hip angles during different ADL tasks and reported a peak hip adduction angle of 17 degrees during putting on shoes, which is very close to our results for the unbraced and non-rigid braced conditions. In addition, comparison of the median peak hip adduction angles between the two braced conditions, demonstrated a 73% and 44% decrease with the rigid brace compared to the non-rigid brace while putting on shoes and walking in an eight-figure, respectively.

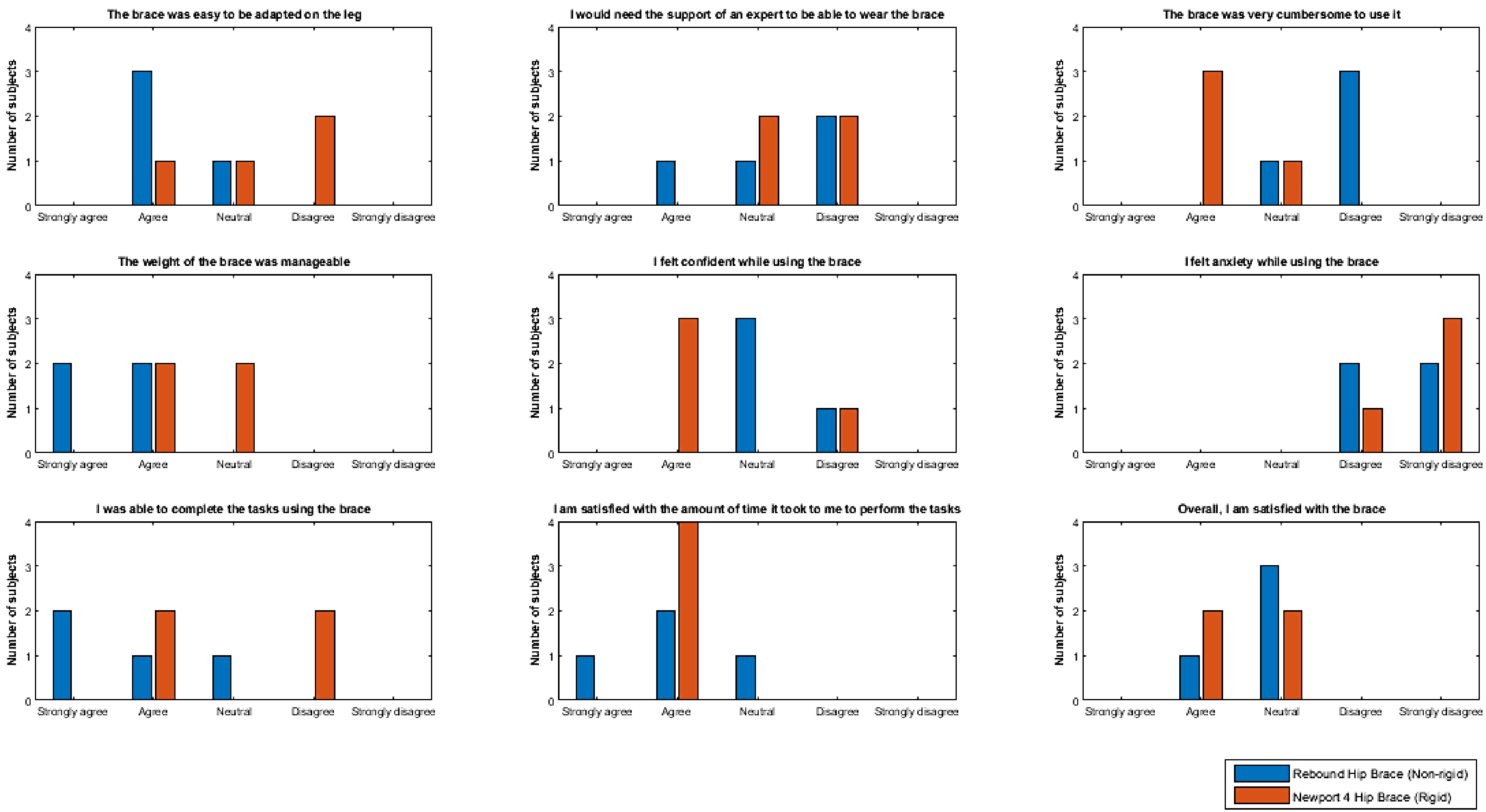

Fig. 4. Participants' perspective of the hip braces
This figure presents the results of the user questionnaires provided to the subjects for the evaluation of the Rebound and Newport 4 hip braces.

An explanation of this noticeable difference after the provision of the rigid brace may be that the sturdiness of its materials prevented adduction to a higher extent, and the individuals were either not able to put their shoes or mainly used their unaffected leg to make the inside turn during the figure-eight movement. In agreement with the results of this study, Wallace et al. [25] also reported no significant effects of a brace on hip adduction, but differences in study design are observed compared to this work, as they used only a non-rigid hip brace (protective strap mechanism) and their testing protocol included only straight walking.

No significant differences were found in the analysis of the transverse hip movement while performing the tasks of putting on shoes and figure-eight movement. Although, the median peak hip exorotation angles wearing the rigid brace decreased by approximately 38% compared to the unbraced condition while putting on shoes, the measured angles cannot be considered as risky for hip dislocation in any case, as the critical point is set at 45 degrees as has also been reported by a review studying the movement restrictions following THA [8]. However, a combined flexion, adduction, and exorotation could be risky for hip dislocation. Future analysis to investigate the combined sagittal, frontal, and transverse hip movement that can pose a dislocation risk is necessary to give insight into this. Additionally, there was an increase of the median peak hip endorotation angles in both braced conditions compared to the unbraced condition. This result may be explained by the fact that some subjects were able to rotate their legs inside the brace, and they also needed to increase their muscle force due to the brace's load in order to make the inside turn.

The secondary aim of the study was to assess the participants' perspective of the braces. We hypothesized that the rigid brace might minimize the comfortability of the subjects during the execution of the ADL tasks, but may be beneficial on preventing risky movements compared to the non-rigid brace due to the sturdiness of its materials. The participants confirmed our hypothesis as they reported that the rigid brace was very cumbersome to use it, and half of them indicated that were also not able to complete the selected ADL tasks.

To our knowledge, this is the first study on effects of different types of hip braces in more than one individual that included sagittal, frontal, and transverse plane hip kinematics during the most demanding ADL tasks found in the literature, and effects on spatiotemporal variables. An important strength of this study is that it also recorded clearly the individuals' perspective regarding the braces. Our findings add new insights to the literature as most of the studies do not specify the relationship between the effectiveness of a brace and the user's perspective of this brace. However, this study found no significant effects of braces provision with respect to the compensatory movement strategies around the hip.

The main limitation of this study was the limited sample size. A valid power calculation to determine sample size was not performed because data of previous studies measuring spatiotemporal and kinematic effects of hip braces provision was not available. Minor effects on spatiotemporal parameters were found, probably because the subjects were measured in specialized gait laboratory which could affect both spatial and timing parameters. Although we found no significant differences on hip kinematics between the unbraced and braced conditions, the median kinematic differences indicate that a bigger sample size could show that differences of braces provision exist. A higher sample size will also give insight into the participants' viewpoint of the braces to establish whether the rigid brace is indeed effective and can be used by the individuals to perform daily activities.

5. Conclusions

The study showed no significant differences in the effects of braces provision on the spatiotemporal variables when the unbraced and braced conditions were compared. However, our findings demonstrated positive short-term effects of braces provision on hip kinematics in non-disabled individuals while performing demanding ADL tasks, based on the median peak hip angles in the three planes of movement. Important median peak differences were found on hip flexion with both braces compared to the unbraced condition, and either hip adduction or exorotation between the unbraced and rigid braced condition. The participants' perspective of the braces indicated that although the rigid brace was more cumbersome to use it compared to the non-rigid brace, it can be more effective on prevention of movements that can pose a dislocation risk.

Conflicts of interest

The authors have no conflicts of interest. The hip braces used in this study were provided by Össur Europe, Eindhoven, the Netherlands and Basko Healthcare, Zaandam, the Netherlands. Össur and Basko were not involved in the study design, collection, analysis, and interpretation of data, or writing of the article. In addition, they had no involvement in the decision to submit the manuscript for publication.

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