provide mobile support, but are designed primarily to compensate for muscle paralysis or weakness or to decrease the metabolic co aid[17]

statistical results from additional (secondary) outcome measures were reported and interpreted only to formulate new hypotheses for further exploration[56–60].

Results

Primary outcome measures. All three assistive controllers (S-D, D, and S) increased the median distance healthy participants ($n = 10$) could walk along a 30 mm-wide (4 m-long) beam by factors of 2.0, 2.0, and 1.6, were not significantly affected by any of the assistive controllers. However, a significant decrease in trunk angle centroidal frequency

Figure 3. Description and main results of Experiment 2. (**a**) Illustration of 'damper' (D) balance controller. (**b**) Balancing tasks with reduced AP or ML bases of support. (**c**) Individual with chronic stroke wearing the GyBAR during AP balancing task over reduced BoS (100 mm). (**d**) Example primary outcomes (stance duration) and time series data for the individual with chronic stroke who exhibited the median degree of improvement with controller D, subject S1 (□). Shown are the trunk pitch angle θ, angular impulse ΔH_{AP}, and exerted gyroscopic moment τ_{AP}. (**e**) Duration standing for all healthy controls ($n = 5$) and individuals with chronic stroke ($n = 5$), normalized to condition 'inactive' (IN) and displayed in logarithmic scale; shown are condition 'free' (FR) and IN and assistive controller D. Subjects H1 (+), H4 (○), and S4 (□) all reached the maximum score in condition D. (**f**) Centroidal frequency of the trunk pitch angle θ for all subjects. The dashed line represents the median value for healthy participants in condition IN with a full BoS.

Qualitative observations. Sagittal balance during normal standing is maintained primarily by moments exerted by the ankle plantarflexors/dorsiflexors[67], but a secondary dynamic hip flexion/extension strategy similar in function to that described for lateral balancing is known to occur in the case that ankle moments are insufficient or their efficacy is inhibited by a small or soft support surface[34,67]. With a reduced AP BoS, a mixture of primary and secondary balancing strategies was visually observed in both subject groups in this experiment. During condition IN, the healthy subjects exhibited persistent and high-frequent ankle plantarflexion/dorsiflexion and varying degrees of secondary hip motion; most performed the task with little or no motion of the upper body and with only minor motion of the knee joints. When controller D was active, little change in overall balancing strategy was observed amongst this group, but the frequency, and in some cases also the amplitude, of joint motions appeared to decrease.

In comparison, during all conditions, the individuals with chronic stroke exhibited clear asymmetry in the joint motions of the lower extremities (activity was visible almost exclusively on the non-paretic side) and a compensatory shifting of activity upwards, resulting in an increase of secondary hip flexion/extension and arm motion; in addition, these secondary strategies appeared to be generally more exaggerated, less coordinated with other body segments, and less consistent within and between subjects than in the healthy group. When the controller (D) was activated, a general reduction of the frequency of all joint motions was visible amongst the individuals with stroke, with compensatory secondary activity of the knees and upper extremities most noticeably reduced. Concurrently, the balance corrections at all sites appeared to be generally less random and more coordinated.

Conclusion

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