A pre-pushing mode was also observed in amputees, consisting of an early thrust exerted by either the sound or prosthetic leg before the classical thrust. It may increase the efficiency of the second classical thrust by initiating a swing. It may also be used to evaluate the support conditions to control the CG position by providing proprioceptive information resulting from a self-controlled activity.

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Toddlers' Postural Control on Different Surfaces

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Little is known about the ability of novice walkers (toddlers) to adapt their postural control to different support surfaces. Contemporary theories of postural development suggest that novice standers possess only a single pattern of muscle activation for maintaining upright stance – a biomechanically simple one producing sway around the ankles (Forssberg & Nashner, 1982; see Woollacott & Sveistrup, 1992). This implies that novice standers should use only ankle rotation to control stance, and that they would have difficulty standing on surfaces that have reduced resistance to the torque that is produced by ankle sway. An example would be a mattress, on which ankle rotation would have a reduced effect on body sway. In previous research children have stood only on flat, rigid extensive surfaces, usually force plates.

An ecological analysis of posture suggests that novice walkers may have access to additional control actions (Riccio & Stoffregen, 1988). On this view, novice standers acquire skills that are keyed to their dynamical relations with the environment: Rather than learning a particular pattern of muscle activations, they learn about the consequences for balance control of using different postural actions on different surfaces. Our purpose was to investigate postural control of new walkers on surfaces varying in rigidity, length, and friction. We were especially interested in their use of ankle and hip motions that are commonly studied in adults. In addition, we provided a means to control posture manually (vertical poles that could be grasped), to see whether very young children would use such support differentially across surfaces.

Method

Ten newly walking 14-month old children were videotaped on four surfaces (semi-randomly ordered and counterbalanced): a tacky plastic over plywood, foam rubber, a wood beam 3.8 cm on a side, and a smooth plastic coated with baby oil). Two 1.9-cm diameter vertical poles were within the child's reach, and could be grasped with one or both hands. Parents encouraged each child to stand without adult support on each surface, while an experimenter stood alongside to ensure the child's safety. Trials ended after 60 s standing freely (without adult support or the poles) or after 120 s total time on the surface. There were two trials on each surface per baby.

Results

Videotapes were coded for postural failures (falls), refusal to stand on the surfaces, duration of holding poles, and details of postural control. Falls were vanishingly rare on all surfaces. All children were able to stand without adult support on all surfaces. Refusals were rare or absent on all surfaces except the beam, on which refusals were common (see Figure 1). Children's inclination to use the poles varied systematically across surfaces (Figure 2); they rarely grasped the poles on the tacky surface, but held them constantly when standing on the beam.

Beyond this, behavior varied in adaptive ways across surfaces. For example, large ankle rotations (foot rocking) and compensatory stepping were more common on the foam, while lowering of the center of mass by bending at the knees was most common on the beam, and smooth sway around the ankles was observed primarily on the tacky and slippery surfaces. Children swayed at the hips only while holding the poles. Kinematic analyses are currently in progress.

Discussion

For free stance, only ankle control was observed, in keeping with the hypothesis of Forrsberg and Nashner (1982). However, the children made frequent use of the poles for postural control. The degree of reliance on the poles was surface-specific,

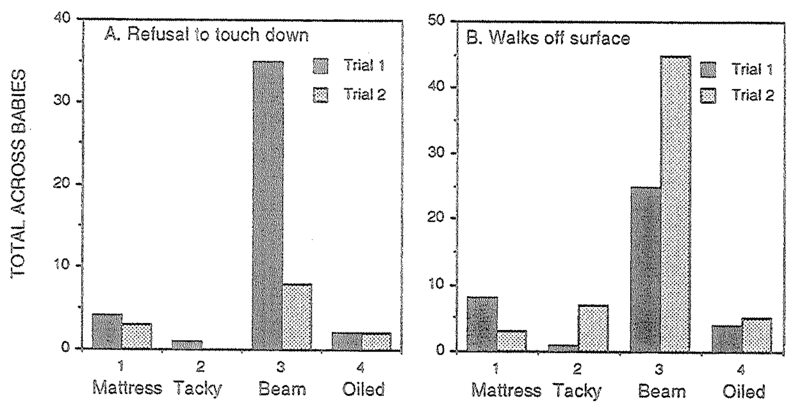

Figure 1. Refusals as functions of surface and trial. Panel A: On being lowered onto the surface the child refuses to use legs for support. Panel B: After being lowered onto the surface the child walks or steps off of it.

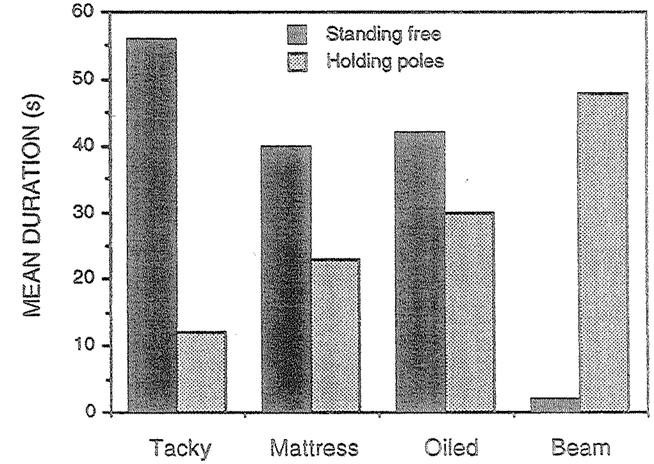

Figure 2. Mean time, across trials and babies, spent in free stance and while holding one or both poles.

suggesting that children perceived the limited value of ankle motions for control on some surfaces. The virtual absence of falls indicates that surface-specific combinations of ankle and manual control were successful. These findings suggest that the children perceived and exploited opportunities for postural support.

Moreover, the data indicate that toddlers are not limited to ankle rotation for the control of posture. At the simplest level this is shown by the adaptive, selective use of the poles, a manual postural-control strategy that has been observed under some circumstances in adults (Cordo & Nashner, 1982). Although hip control was not observed during free stance, it was apparent when the poles were in use. Apparently, toddlers can control the hip joint during upright stance; however, the restriction of hip control to pole-stance suggests that it is not yet sufficient to manage the entire mass of the upper body. The absence of both hip motion and falls in free stance suggests that toddlers are aware of their limited hip-control capabilities, and avoid strategies likely to lead to falling.

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Contributions of Peripheral and Central Vision to Long Jumping

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Despite evidence of the importance of optic flow to perception of movement, the literature is relatively silent on the region of the visual field used for its assessment. Early studies of movement perception clearly demonstrated that peripheral vision was important in the perception of self-motion (Dichgans & Brandt, 1978). More recently, Andersen (1986) emphasized that information from central vision can also affect the perception of self-motion. Hence it appears that both peripheral and central vision may be important. Few studies, however, have investigated the possible contribution of central and peripheral vision to sporting performance. An early summary article of Russian research outlined the deleterious effects that elimination of peripheral vision had on a range of sports, namely javelin, hammer and discus throwing, figure skating, and slalom skiing (Graybiel, Jokl, & Trapp, 1955). Furthermore reductions in performance were more marked than those observed following loss of central vision. More recently, Laurent, Paul, and Cavallo (1988) have demonstrated the importance of peripheral vision for accurate foot placement on a target.

The present study investigated the use of peripheral and central vision while long jumping. Long jumping was selected for two reasons. First, it involves a relatively straightforward pattern of optic flow, that is, primarily linear vection. Sport with a translational optic flow was selected because use of the central region of the retina for motion perception has only been reported for linear vection (see Andersen, 1986). Running per se was not considered suitable because the Russian research noted no effects of visual restriction on this task. Secondly, evidence already exists for the use of optic flow variables in long jumping, (Berg, Wade, & Greer, 1994; Lee, Lishman, & Thomson, 1982).

Method

Eight female and 7 male sport science students aged between 19 and 21 years performed 9 jumps, three under each condition. None of the participants were specialist long jumpers. Lightweight goggles were employed for restriction of visual input. Elimination of peripheral vision was achieved with 3.6 cm diameter tubes attached to the goggles so that the end of the tube was on average 8 cm from the pupil (field size of 25.3° of central vision). For elimination of central vision, a black, circular spot 1.9 cm in diameter was positioned on a pair of clear goggles on average 2 cm from the pupil. This resulted in removal of central vision (missing field size of 53.1°).