Manual Asymmetry During Object Release Under Varying Task Constraints

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OBJECTIVE. This study examined differences between the dominant and nondominant hands of children during an object release task under various accuracy and speed constraints.

METHOD. Fifteen children 7 to 14 years of age who were typically developing released an instrumented object held with a precision grip onto a stable or unstable surface at a self-paced or quick speed while temporal and force measures were recorded.

RESULTS. Few differences were found between the two hands under stable, self-paced conditions. However, given accuracy constraints, object replacement with the nondominant hand took longer than the dominant hand. The nondominant hand exhibited different force coordination patterns than the dominant hand when both accuracy and speed constraints were imposed.

CONCLUSION. Task constraints differentially affected the performance of the dominant and nondominant hands during this object release task. The results suggest that clinicians should incorporate various task constraints into hand preference evaluations and during “dominance retraining.”


O ccupational therapists traditionally have had a keen interest in the issue of hand preference (Clark & Allen, 1985; Clerke & Clerke, 2001; Knickerboker, 1980). Children who are delayed in developing a consistent preference commonly are recommended for occupational therapy because of its presumed effects on fine motor skills, bilateral coordination, and midline crossing (Fisher, Murray, & Bundy, 1991; Stilwell, 1987). In addition, patients with hemiplegia, hand injury, or upper-extremity disease often require “dominance retraining.” Although a common assumption is that performance of the nondominant hand is significantly diminished compared with the dominant hand, previous studies, particularly those involving kinematic and kinetic analysis, have yielded differing results. A major concern of occupational therapy also has been the identification of task parameters and conditions that affect performance through the use of task analysis. Therefore, it is important to understand what task conditions influence asymmetrical hand skill for both assessment and treatment purposes. Yet, little is known about how performance differences between the dominant and nondominant hands are affected by task conditions, and few studies within the occupational therapy literature have addressed this issue (Larkin, 1989; Walsh, Belding, Taylor, & Nunley, 1993).

Literature Review

Hand preference, or the tendency to favor one hand over the other for the performance of skilled motor tasks, is an intriguing feature of human development.
Whether the source of manual asymmetry is primarily neuroanatomical (e.g., Amunts et al., 1996) or experiential (e.g., Peters, 1976; Provins, 1997) in nature is still a highly debated issue. Regardless, it is well established that for certain tasks the dominant hand is superior to the nondominant hand. In particular, the dominant hand has been found to be faster (Peters & Durding, 1979; Todor & Kypric, 1980; Todor & Smiley-Oyen, 1987), more accurate (Annett, 1985; Annett, Annett, Hudson, & Turner, 1979; Todor & Cisneros, 1985), and less variable in timing (Peters & Durding, 1979; Todor & Kypric, 1980, Todor & Smiley-Oyen, 1987) than the nondominant hand for commonly studied finger tapping and pegboard tasks. Superior performance of the dominant hand has been attributed to a variety of factors, such as the processing characteristics of the left-hemisphere–right-hand system (e.g., Roy & MacKenzie, 1978), task complexity (e.g., Flowers, 1975; Todor & Cisneros, 1985; Walsh et al., 1993), practice (e.g., Peters, 1976; Provins, 1997), and type of muscle groups (proximal vs. distal) used for a task (e.g., Hore, Watts, Tweed, & Miller, 1996).

Although these studies report between-hand differences, the tasks used (finger tapping speed, pegboard completion tasks) are not representative of typical activities of daily living. Only a few reported studies have investigated hand differences by using kinematic (description of movement in terms of linear and angular displacements, velocities, and accelerations [for further description, see Ma & Trombly, 2001]) and kinetic (the description of the forces that cause the movement) analyses of functional movements. These methods allow researchers to make more definitive assessments and interpretations about human movement (Winter, 1990). Interestingly, both kinematic and kinetic analyses have revealed few differences between the dominant and nondominant hands.

Gordon, Forsberg, and Iwasaki (1994) studied the fingertip force coordination of both hands during a precision grasp-lift task in children and adults. They did not find any differences between hands. These results may have been due to the nature of the task studied because the precision grasp pattern is commonly performed by the nondominant as well as by the dominant hand (e.g., grasping a small container with the nondominant hand to open it with the dominant hand). Therefore, it is possible that their grasp-lift task was not as strongly lateralized to one hand as would be a more demanding prehensile task such as handwriting, which is primarily performed with one’s dominant hand. Indeed, a kinematic study showed that handwriting speed was degraded and that writing strokes were more variable for the nondominant hand (Phillips, Gallucci, & Bradshaw, 1999). Sainburg and Kalakanis (2000) also found specific kinematic (trajectories, hand paths) and kinetic (coordination of muscle and intersegmental torques) differences between hands during rapid targeted reaching, which is not a strongly lateralized task. However, their study included speed and accuracy constraints.

No kinetic studies to date have investigated differences between hands during functional tasks that demand high precision, such as is required during object release. Specifically, object release demands the precise coordination of fingertip forces and timing for predicting object placement on-line (during the movement) so that the object does not drop or hit the support surface too forcefully (Eliasson & Gordon, 2000). Hence, temporal and force coordination during object release may reveal greater hand differences than the tasks studied previously. In addition, because task context has been found to affect motor skills (e.g., Haley, Coster, & Binda-Sundberg, 1994; Ma, Trombly, & Robinson-Podolski, 1999), examining the effects of changes in context by varying task constraints also may help to clarify which components of this task influence the asymmetry between hands.

The purpose of this study was to investigate the force coordination patterns during object release to determine whether differences exist between the dominant and nondominant hands for this functional task. Additionally, task constraints of speed and accuracy were included to elucidate specific conditions in which the differences may emerge. The two questions addressed were:

1. Do the dominant and nondominant hands perform differently during object release under natural conditions?
2. Is there a greater difference between hands when constraints are applied to the task?

Because previous studies have found differences in speed, accuracy, and variability between hands (e.g., Phillips et al., 1999; Todor & Cisneros, 1985; Todor & Smiley-Oyen, 1987), we hypothesized that the dominant and nondominant hands would exhibit differences in temporal components, force coordination, and variability during object release, particularly when speed and accuracy constraints were required.

**Method**

**Participants**

Fifteen healthy children (8 girls, 7 boys) 7 to 14 years of age participated in the study. This age group was selected because grasping behavior typically approximates that of adults by 6 to 8 years of age (Gordon, in press). In addition, handedness is clearly evident by this age (Ounsted, Cockburn, & Moar, 1995), allowing generalization to both children and adults. Children were recruited from the New
York City metropolitan area schools. Inclusion criteria were the ability to grasp, lift, and release a 300 g object onto an unsteady surface and normal cognitive abilities within 2 standard deviations of the mean on the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990). Children were all right-hand dominant as assessed by parent–child report, and right-hand dominance was confirmed with the Edinburgh Handedness Inventory (Oldfield, 1971). Informed consent was obtained from children and parents, and the study was approved by the local Institutional Review Board.

**Instruments**

A custom-made grip instrument was used to measure gertip forces from two parallel (#200 grit sandpaper) contact surfaces, 30 mm in diameter and 45 mm apart (see a in Figure 1A). The grip surfaces covered force torque sensors. Grip (pinch) force measures from each contact surface and total load (vertical) force from both surfaces were measured (.025 Newton [N] resolution). The total weight of the object was 265 g. An electromagnetic position-angle sensor signaled the vertical position of the object (.75 mm resolution) (see b in Figure 1A).

**Procedure**

The experimental set-up is illustrated in Figure 1B. Each child stood at an adjustable-height table so that a horizontal bar (25.5 cm above a platform resting on the table surface) was aligned at shoulder height. The children were instructed to grip the instrument (see a in Figure 1B) between their thumb and index and middle fingers; lift it 25.5 cm until the top of the instrument touched the horizontal bar, which served as a vertical marker (see b in Figure 1B); and hold it in the air for several seconds. After an auditory cue, which was unpredictable in timing, the children replaced the object onto a stable platform resting on the table surface (see c in Figure 1B). This condition was denoted as stable. For the unstable (or accuracy) condition, the children replaced the object onto an unstable support surface (upside-down plastic vase) (see d in Figure 1B), which was also 25.5 cm below the horizontal bar. The narrow (6-cm diameter) unstable support surface would topple if the grip instrument was not placed in its center. The stable and unstable conditions were performed in that order for 5 trials each at the child’s preferred speed (i.e., no directions regarding speed were provided) with the dominant and nondominant hands. The order was counterbalanced between the dominant and nondominant hands. After the preferred speed trials for the stable and unstable conditions with each hand, the procedure was repeated but with instructions to replace and release the object “as fast as possible” after the auditory cue. The fast speed trials were performed after the preferred speed trials so as not to influence the natural speed during self-paced trials. The experimental conditions (as in the following example, beginning with the dominant hand) were ordered as follows, with 5 trials for each condition (totaling 40 trials):

- Dominant hand, stable surface, preferred speed
- Dominant hand, unstable surface, preferred speed
- Nondominant hand, stable surface, preferred speed
- Nondominant hand, unstable surface, preferred speed
- Dominant hand, stable surface, fast speed
- Dominant hand, unstable surface, fast speed
- Nondominant hand, stable surface, fast speed
- Nondominant hand, unstable surface, fast speed

**Data Collection and Analysis**

Signals from the grip instrument were sampled at 400 Hz and digitized with a 12-bit resolution using the SC/ZOOM data acquisition and analysis system. Data were stored on a personal computer and analysis performed with the use of the system’s graphics terminal. The graphics terminal was used interactively to define the temporal and force parameters (see Figure 1C). The release task was divided temporally into three phases (see Eliasson & Gordon, 2000). Briefly, the (a) replacement phase (Figure 1C, T0–T1) began with a criterion of three consecutive position decreases and ended when the position signal reached less than .2 mm, which signified object down; (b) the release phase (Figure 1C, T1–T2) was determined from object down until release of the first digit’s grip force (< 0.1 N); and (c) the finger difference phase (Figure 1C, T2–T3) measured the temporal delay between the release of each digit from the contact surface.

Velocity (mm/s), grip force rate (dGF/dt) and load force rate (dLF/dt) (see Figure 1C) were calculated using a ± 5-point numeric differentiation (i.e., calculated within a 10-ms window). Peak velocity was measured during the replacement phase (Figure 1C, F1) and just before object down at position 5 mm (Figure 1C, F2). The maximum rate of load force decrease (Figure 1C, F3), which coincided with the object down criterion, was documented (i.e., as the object hit the surface). The maximum rate of grip force decrease (Figure 1C, F4) also was measured as well as the time to maximum grip force rate taken from the point of object down. Grip force was measured at three points: (a)

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1Nano F/T transducer, ATI Industrial Automation, 1031 Goodworth Drive, Apex, North Carolina 27502.

2Polhemus, Fastrak, 40 Hercules Drive, PO Box 560, Colchester, Vermont 05446.

3Umeå University, SE-901 87 Umeå, Sweden.
Figure 1. A. Schematic diagram of the grip instrument, with grip surfaces covering force transducers (a) and electromagnetic position sensor (b). B. Schematic diagram of the experimental set-up, including the grip device (a) lifted to the horizontal bar, which served as a vertical marker for the lifting height (b); the stable surface on which the object was replaced for normal conditions (c); the unstable surface on which the object was replaced for accuracy conditions (d); and the Polhemus position transmitter (e). C. Grip force from the index finger (ind) and thumb (th), grip force rate, load force, load force rate, vertical position, and velocity for a representative trial with the dominant hand during object release under stable, self-paced conditions. Vertical lines indicate the initiation of replacement or vertical displacement of the object (T0), object contact with the table (T1), release of one digit (T2), and release of the opposing digit (T3). The measured force parameters are indicated by arrows showing peak velocity (F1), velocity before object down (5 mm) (F2), maximal load force rate associated with object down (F3), maximal grip force rate (F4), grip force at the initiation of replacement (F5), and grip force at object down (F6). Values to the right of the figure provide a numeric scale.

Note: N = Newtons.
while the object was held in the air for 2 sec before replacement (mean static grip force was calculated), (b) at the initiation of the replacement phase (Figure 1C, F5), and (c) at object down (Figure 1C, F6). In addition, the coefficients of variation (SD/M) were taken for each measured variable and used to determine variability within participants. Statistical comparisons used a three-way (hand × accuracy × speed) repeated-measures analysis of variance (ANOVA). Statistical significance was considered at the $p < .05$ level.

**Results**

**Temporal Coordination of Object Release**

To release an object to a surface efficiently, the timing of movement phases and fingertip forces must be precisely coordinated for on-line placement predictions. Figure 2 shows trials from a representative participant during object release for both the dominant and nondominant hands under stable (top) and unstable (bottom) conditions and
performed at a preferred speed. More specifically, the grip and load forces, their rates of change, and the position and velocity traces are depicted. Under the stable condition (top), the overall task (T0–T3) and each of the three temporal phases comprising the task (replacement time [T0–T1], release time [T1–T2], finger difference time [T2–T3]) were of similar duration for both hands. However, when accuracy (bottom) was required for the same task (i.e., when the participant placed the object on an unstable surface), the overall task duration (T0–T3) increased for both hands compared with the stable condition. Furthermore, under unstable conditions, a marked increase was found in replacement time (T0–T1) for the nondominant hand. Release and finger differences remained generally comparable in time.

Figure 3 shows that these findings were representative of the participants. The figure includes the means (± SEM) of replacement time, release time, finger difference time, and time of peak grip force rate for the stable and unstable conditions. Because speed did not affect hand differences for any temporal measure (hand × speed interaction, *p* > .05, in all cases), the values for the two speeds (preferred, fast) were combined in Figure 3. As seen in the figure, all three phases were longer when the task required increased accuracy (*p* < .05), as was expected. In addition, a significant increase was found in replacement time for the nondominant hand compared with the dominant hand when accuracy was required (Figure 3A) (hand × accuracy interaction, *p* < .01). Neither release (Figure 3B) nor finger difference (Figure 3C) duration differed significantly between the dominant and nondominant hands (*p* > .05), despite a trend noted for finger difference in the unstable condition. Thus, the temporal components of object release do not differ significantly between the dominant and nondominant hands under stable, preferred speed, or even fast speed conditions. However, the task is performed more slowly with the nondominant hand when accuracy (unstable condition) is required because of a prolonged replacement time.

Similarly, during the unstable condition, the temporal pattern of the peak grip force rate (i.e., the rate at which the grip force decreases once the object is replaced) differed significantly between the dominant and nondominant hands, as seen in Figure 3D (confirmed by a hand × accuracy interaction, *p* < .05). The time of the greatest decline of grip forces occurred closer to when the object contacted the table surface for the nondominant hand when accuracy was required. This different strategy used by the nondominant hand resulted in a more abrupt release of the object. Under the stable condition, the nondominant hand exhibited a more gradual decline of grip forces from the time the object reached the table surface, as seen in the higher time value from object down. In contrast, the dominant hand displayed nearly equal timing of peak grip force rates under the stable and unstable conditions (Figure 3D). Although the time of peak grip force rate in the nondominant hand was markedly closer to table contact for the unstable condition, the peak amplitude of grip force rate (not shown) was not significantly altered between hands (*p* > .05). Thus, when accuracy is required, an abrupt release of the object also occurs with the nondominant hand.
Coordination of Forces and Movement During Object Release

In addition to temporal control, the coordination of grip forces, load forces, and velocities are necessary to release an object onto a surface in a smooth and skilled manner. Normally during object release, grip forces decrease gradually in anticipation of the object’s replacement and release to the support surface. In addition, velocity should decrease before the time the object contacts the surface to “dampen” the vertical contact force (Eliasson & Gordon, 2000) when it reaches the surface. Figure 4A illustrates the mean grip forces used during the static phase, at the initiation of replacement, and when the object contacted the table. In all conditions, the dominant hand demonstrated a consistent sequence of step-like decreases in grip force in preparation for object replacement and table contact, respectively. Specifically, slight decreases were found in grip force relative to the static phase at the initiation and termination of replacement. The same was true for the nondominant hand under the stable, preferred speed condition. In contrast, the nondominant hand exhibited changes in strategy whereby there were random increases and decreases in grip force when accuracy and speed constraints were introduced separately (confirmed by a hand × phase × accuracy × speed interaction, \( p < .05 \)). When the task became highly constrained with increased accuracy and speed imposed together...
er, a step-like pattern resumed in the nondominant hand similar to the anticipatory grip force decreases of the dominant hand seen in Figure 4A. Thus, performance of the nondominant hand involved less coordinated anticipatory control of grip forces when accuracy and speed constraints were introduced separately. However, when both constraints were applied together, the nondominant hand had similar force coordination to the dominant hand.

Peak velocity of object replacement (not shown) did not differ significantly between hands. However, velocity before table contact (Figure 4B), used as a measurement of dampening just before table contact, differed between hands when speed and accuracy requirements were manipulated (hand x accuracy x speed interaction, \( p < .05 \)). As seen in Figure 4B, the velocity of the nondominant hand was not dampened as much (indicated by a high velocity) as the dominant hand when moving quickly under stable conditions perhaps because this did not affect successful task performance. However, when the nondominant hand was required to release the object quickly to the unstable surface, the velocity was dampened, resulting in similar velocities between the two hands (Figure 4B). Thus, when accuracy and speed constraints were imposed together, the nondominant hand was able to perform more similarly to the dominant hand. Successful performance was confirmed by the fact that none of the release trials resulted in the object being dropped.

Variability

The degree of variability between trials was analyzed to determine whether differences in consistency of performance existed for the dominant and nondominant hands. Coefficient of variation measures were compared between hands for each variable under all conditions. Although most variables did not differ in terms of variability between hands (\( p > .05 \)), the nondominant hand exhibited greater overall variability for finger difference time when either increased speed or accuracy was required (hand x accuracy x speed interaction, \( p < .05 \)) (see Figure 5A). In addition, greater overall variability was found for the peak grip force rates of the nondominant hand under all conditions (indicated by a main effect for hand, \( p < .05 \)) (Figure 5B). This finding indicates less consistent performance for these variables in the nondominant hand.

Discussion

As shown previously in the study of a grasp-lift task (Gordon et al., 1994), this study demonstrated few differences between the dominant and nondominant hands when object replacement and release were performed naturally (i.e., onto a stable surface at a preferred speed). However, in agreement with our original hypothesis, temporal and force coordination and variability differences emerged when accuracy constraints were imposed. Speed constraints had a differential effect on the coordination of forces and movement and on variability. The application of accuracy together with speed constraints resulted in similar force and movement coordination patterns for both hands. These findings and their theoretical implications and clinical relevance are discussed.
Differences Between Hands

Differences in temporal measures for the two hands were elicited only when releasing to the unstable surface, a condition requiring greater accuracy. The dominant hand replaced the object faster than the nondominant hand when it had to be placed accurately onto an unsteady surface. Hore et al. (1996) also identified differences in timing measures for the two hands during a throwing task that required accuracy. They attributed these differences to the timing and coordination of proximal and distal joints. Our findings coincide with this notion because object release, particularly to an unstable surface, requires proximal (shoulder and elbow) coordination with distal (wrist and finger) control. The temporal coordination for our task similarly was found to be superior in the dominant hand. In addition, the time in which fingertip forces decreased most rapidly (peak grip force rate) differed between the two hands when accuracy requirements were increased. The dominant hand appeared to use a more efficient strategy of decreasing its grip forces after the object's contact with the table surface. In contrast, the nondominant hand coped with the accuracy constraints by decreasing the grip forces sooner and closer to the object's contact of the table surface, resulting in a more abrupt release.

Increasing the speed requirements alone did not account for significant temporal differences between the hands. This finding agrees with a number of reaching studies that do not show dominant arm advantages during "ballistic" (high speed, low accuracy) movements but that show advantages emerging when accuracy requirements of the experimental task increase (e.g., Flowers, 1975; Todor & Cisneros, 1985). However, in this study, speed constraints did promote force and movement coordination differences between hands. The grip forces were well coordinated for the dominant hand and exhibited a consistent strategy of step-like grip force decreases throughout the course of the movement and release. When speed constraints were introduced, the nondominant hand appeared to use more varied and less efficient patterns of grip forces throughout the course of the movement. Additionally, the strategy of dampening (or decreasing) the velocity just before the object's contact with the table surface was not efficiently used by the nondominant hand when speed requirements were imposed. These findings agree with those of Sainburg and Kalakanis (2000), who reported less efficient force coordination strategies for the nondominant limb in a reaching task involving speed constraints.

Finally, the findings of increased variability between trials in the nondominant hand for both the time between removal of each digit from the object (finger difference) when accuracy and speed constraints increased and the rate of grip force decline (peak grip force rate) under all conditions support the notion that the nondominant hand is less consistent in its performance than the dominant hand (Phillips et al., 1999; Sainburg & Kalakanis, 2000). Together, the less efficient and more variable force coordination for the nondominant hand under accuracy and speed constraints provide further evidence of the nature of hand differences and how task conditions affect these differences.

Similarities Between Hands

The limited temporal and force coordination differences between the dominant and nondominant hands under preferred speed and low accuracy conditions in this study support prior studies reporting negative findings (e.g., Gordon et al., 1994). Interestingly, when accuracy and speed constraints were imposed together in the present study, the coordination of forces and movement of the nondominant hand resumed more efficient, anticipatory patterns similar to those of the dominant hand. This finding has not been reported in previous studies possibly because of the unique set-up and nature of this particular task. Imposing high accuracy and speed constraints during object release requires that the nondominant hand perform the task in an efficient and coordinated manner. Otherwise, the object would drop. Thus, when the constraints imposed necessitated it, the nondominant hand was able to use force and movement coordination patterns similar to that of the dominant hand.

Theoretical Implications

The findings of decreased temporal, force, and movement coordination and decreased consistency of performance in the nondominant hand under task constraints can be viewed from different theoretical frameworks. Peters (1976) and Provins (1997) proposed that the level of experience and practice for a particular task are the primary influences on differential performance between hands. Thus, release to a steady surface at a preferred speed commonly may be performed with either hand, whereas release under accuracy constraints and speed constraints is performed and, thus, practiced more often with the dominant hand. Furthermore, the finding that accuracy evoked the most striking differences between hands also could be attributed to practice because replacing and releasing an object rapidly more likely may be performed with either hand than replacing it precisely.

Other studies have taken a less dynamic approach toward manual asymmetry, focusing on the neural basis for these differences rather than on experiential contributions.
(e.g., Amunts et al., 1996). According to this idea, whether the neural asymmetries are in the motor cortex, basal ganglia, or cerebellum (Amunts et al., 1996; Kooistra & Heilman, 1988; Snyder, Bilder, Wu, Bogerts, & Lieberman, 1995), differences between hands are said to emerge as a result of distinct neural circuitry in each hemisphere. The behavioral effects of hand preference would be determined neurally before the opportunity for experience and practice exists. This hypothesis is supported by hand preference evident in human fetuses and newborns (i.e., before practice occurs) (e.g., Hepper, Shahidullah, & White, 1991; Tan, Ors, Kurkcuoglu, Kutlu, & Cankaya, 1992). Although our results cannot distinguish between these two potential causes of hand asymmetry (nature vs. nurture), both likely play important roles whereby a preference naturally occurs and is subsequently reinforced with practice.

Clinical Implications

The finding that hand differences are more likely to emerge with the addition of task constraints has important applications for the evaluation and treatment of children who do not exhibit clear or consistent hand dominance. Formalized assessments and inventories and informal clinical evaluations of hand preference should include tasks with accuracy and speed components to clarify differences between hands. Furthermore, assessments that evaluate and report developmental age ranges for the performance of accuracy tasks, such as in-hand manipulation (e.g., Exner, 1990; Pehoski, Henderson, & Tickle-Degnen, 1997a, 1997b), should include evaluation of and data for both the nondominant and the dominant hands because they may differ.

For patients with acquired injuries to their dominant hand (e.g., upper-extremity injuries, hemiparesis), the findings of little differences between performance of the dominant and nondominant hands under natural conditions (low accuracy, preferred speed) lend support to switching to the nondominant hand for certain tasks and under certain conditions. However, because our results show decreased efficiency of the nondominant hand under accuracy and speed constraints, therapists must develop a treatment plan that is based on the task constraints with which these patients will encounter difficulty (particularly high accuracy and speed requirements). Practical implications of these deficits involve release under constraints during common activities, such as stacking blocks onto an unstable block tower for children, releasing fragile objects, or releasing a full and hot coffee mug (a task that demands high accuracy and speed) for adults. Because the effects are task specific, therapists must provide practice with specific task constraints when retraining the nondominant hand for a particular skill. Thus, for a patient to be able to perform functional release in everyday life experiences with his or her nondominant hand, he or she should be proficient in release not only to a stable surface, but also to many surfaces with varying levels of stability and at different speeds. Training of functional release may therefore require longer and more intensive therapeutic intervention. Understanding differences between hands and their implications for intervention with patients who have acquired upper-extremity injuries could be used to promote evidence-based practice and allow for the justification of ongoing occupational therapy services to maximize functional competence.

Limitations

Limitations of this study include the use of 7- to 14-year-old children who are typically developing. Although grasping behavior generally approximates that of adults by 6 to 8 years of age (Gordon, in press), this correlation has not yet been evaluated and established for the performance of object release. Therefore, generalization of our results to other populations (preschoolers, adults, elderly persons, children with disabilities) must be done with caution. In addition, this task was performed by participants during a one-time visit and does not address the element of practice and prior experience, which may be important for relating the findings to therapeutic settings that involve longer term training and rehabilitation. Finally, although this study contributes to our understanding of the consequences of manual asymmetry, it does not address the mechanisms underlying these asymmetries. Therefore, further research in this area is warranted to enhance our knowledge of hand preference and its effect on skilled performance.

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