Upper limb impairments, process skills, and outcome in children with unilateral cerebral palsy

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AIM To examine the relationships between upper limb impairments and independence in self-care (ISC) in children with unilateral cerebral palsy (CP).
METHOD One hundred and eight children with unilateral CP (46 females, 62 males; mean age 8y 7mo, SD 3y 9mo) recruited from a population register were assessed for upper limb muscle power, spasticity, sensation, motor control, and process skills, and for ISC as the functional outcome using structural equation modelling.
RESULTS The model showed good fit indices and explained 90% of the variance in ISC. Direct effects were significant between manual ability and ISC (β=0.47), and process skills and ISC (β=0.63). Sensation had a significant positive indirect effect on ISC through manual ability (β=0.24) and a positive but marginally non-significant indirect effect through process skills (β=0.21, bootstrapped 95% confidence interval −0.05 to 0.55). Spasticity had a significant negative indirect effect on ISC through its effect on manual ability (β=−0.21). Age had a significant positive indirect effect on ISC, as did intellect, through their effect on process skills (β=0.34 and 0.21 respectively).
INTERPRETATION ISC is affected by upper limb impairments and process skill. Sensation influences ISC through its effects on manual and process skill abilities. Both sensation and process skills require further evaluation to assist ISC in children with unilateral CP.

Children with unilateral cerebral palsy (CP) experience several positive and negative features due to the upper motor neuron syndrome.[1,2] Impairments that interfere with function include reduction in upper limb muscle power[3–7] and sensation,[1,8–12] increased muscle spasticity,[3] and lack of motor control.[9–13] Owing to these impairments, children with unilateral CP experience significant upper limb dysfunction and disability.[14,15] Despite these limitations, children with unilateral CP are in the subgroup of children with CP most likely to have to function at school and in the community alongside typically developing peers,[16,17] presenting significant issues they need to overcome to be competitive in that environment.

Clinicians choose therapeutic interventions to reverse or ameliorate the influence of these impairments for functional improvement, as part of a more holistic approach of therapeutic intervention using the International Classification of Functioning, Disability and Health (ICF) model.[18] Therapy is often aimed at the most significant impairments felt to be contributing to a reduction in functioning in an ad hoc fashion. Finding a unifying model to assess the relative contributions to functional outcome to prioritize therapy has not been assessed systematically and remains elusive. In studies evaluating impairments in children with unilateral CP and CP generally, there have been significant deficiencies including small numbers of participants,[3,4,9,13] heterogeneous forms of CP,[4,13] and non-representative samples of children recruited mainly from hospital settings.[13] It is also important to consider other measures that can influence functional outcome, including age[5,13,19,20] and cognitive skills.[21]

In their seminal article assessing the relationship between spasticity, muscle power, gross motor function, and functional outcome in children with CP, Kim and Park[22] found that weakness and spasticity were factors related to functional outcome, as mediated through gross motor function. However, they did not assess function as defined by independence in self-care (ISC), and they did not include an evaluation of sensory function or process skills. The aim of our study was to quantify the association between the clinical concepts of manual ability, spasticity, sensory function, and process skills and ISC in children with unilateral CP while controlling for age and intelligence.

METHOD

We assessed 108 children with spastic unilateral CP recruited from a population register to evaluate upper limb

impairments and construct a theoretical and statistical model to describe the relative contributions of muscle power, motor control, sensation, spasticity, age, intellect, and process skills on functional outcome as defined by ISC using structural equation modelling (SEM). This method of analysis utilizes latent variables, such as ISC, that are defined by their manifest indicator variables.[23] A theoretical framework postulated the likely relationships of the independent (exogenous) latent variables to the dependent (endogenous) variable of ISC. Previous studies allowed for some of the paths to be established (e.g. age, strength, and spasticity) and some were postulated when assessing correlations of impairments with functional outcome (e.g. sensation).

Participants

A community-based sample of 108 children with unilateral CP (mean age 8y 7mo [SD 3y 9mo; range 3–16y]; Gross Motor Function Classification System [GMFCS] level I=86 [79.5%], GMFCS level II=15 [14.0%], GMFCS levels III–V=7 [6.5%]; 46 females, 62 males; 59 with right-sided hemiplegia; typical IQ in 72%) recruited from a CP population register underwent a cross-sectional evaluation. All children on the register with a diagnosis of unilateral CP were approached by mail and then had a telephone follow-up. Informed written consent to participate in the study and for publication of the results was obtained from all parents. Approval was granted by the Women's and Children's Hospital and the Flinders University Ethics Committees.

Observed measurements

The Assessment of Motor and Process Skills (AMPS) was administered in the children's home and all other measures either in their home or in a clinic setting. ISC was described by the motor component of the AMPS,[24] the Pediatric Evaluation of Disability Inventory[25] caregiver section, and the CP Register Assessment of Bimanual Upper Limb Function.[15,26] The AMPS is a reliable and valid tool measuring instrumental activities of daily living.[27] Two activities the child undertakes regularly are assessed, evaluating actions used to complete the task.[28] Higher logit scores (−3 to +3) indicate greater motor abilities. Daily living tasks of meal preparation (44%), dressing (35%), household chores (12%), or self-care (9%) were chosen by the participants. The Pediatric Evaluation of Disability Inventory caregiver section is valid and reliable[29] and consists of 73 capability items in 15 skill areas[25] of task completion without the assistance of a caregiver,[30] with scores ranging from 10 to 73. This covers such items as eating, grooming, toileting, and dressing. The CP Register Assessment of Bimanual Upper Limb Function is an ordinal scale reporting difficulty in dressing and feeding assessed at approximately 5 years of age, with 1 indicating an inability to put on a shirt and feed themselves, to 4 indicating no problem with bimanual tasks. Data were extracted from the South Australian Cerebral Palsy Register[26] for IQ, gross motor

What this paper adds
- Process skills and manual ability most strongly positively influence independence in self-care (ISC) in children with unilateral cerebral palsy.
- Sensation influences ISC through manual ability and process skill.

ability (GMFCS),[31] and CP Register Assessment of Bimanual Upper Limb Function. Age, sex, and affected side were collected at the time of review.

Manual muscle testing used the power rating scale, with 0 indicating no movement and 5 indicating antigravity movement with maximum resistance.[32] This assessment has moderate to high reliability in children with unilateral CP.[33] The affected side for elbow and wrist flexion was rated. Supination strength was evaluated using a modification of the pronation deformity classification.[34] This ordinal tool has five levels, with '5' indicating active supination beyond neutral and '1' indicating no active supination with tight passive supination. Children were assessed for motor control using the Manipulative Hand Skills, the Dynamic Interference of Abnormal Tone Upper Limb, and the South Australian Cerebral Palsy Register classification of hand function for hemiplegia. The Manipulative Hand Skills is an ordinal measure of hand function adapted from McCue et al.[35] with six levels, from '0' (no voluntary hand function) to '5' (complex in-hand manipulations). The Dynamic Interference of Abnormal Tone Upper Limb[36] is an ordinal measure with six levels of control, from '0' (no voluntary movements) to '5' (normal movements) grading voluntary movements sequentially from the shoulder through the elbow, wrist, hand, and fingers. The South Australian Cerebral Palsy Register classification of hand function for hemiplegia[26] is an ordinal scale with five levels describing unilateral function, with '1' indicating a nonfunctional upper limb and '5' indicating no apparent problem. In the preliminary analysis of the data, measures of muscle power and motor control showed very high correlation coefficients and a decision was made to bring the six motor control and muscle power measures together as one latent variable in the model labelled 'manual ability'. This is consistent with clinical observations that muscle power is an essential component of normal motor control.[37]

For tests of sensory function, vision was occluded. First the unaffected hand, then the affected hand, were tested for stereognosis, finger identification, two-point discrimination, and graphesthesia. For stereognosis, 10 objects were sequentially placed in the hand for identification by the child (toy car, pencil, flannel, ball, key, safety pin, coin, marble, button, and toothbrush). For graphesthesia, the figures I, O, V, 8, X, and 3 were drawn in the palm of the hand. For two-point discrimination, the palmar aspect of the fingertips of all five digits was tested using a standard distance of 8mm.[8] For finger identification, all five digits were touched with a cotton tip on the palmar aspect and in random order, and the child had to identify which digit was stimulated. Only data from the affected upper limb were used in the model. These tests of sensory assessment have very good reliability in children with unilateral CP.[33]

Spasticity was assessed at the elbow and wrist using the Modified Ashworth Scale[38] and Modified Tardieu Scale.[39] The Modified Tardieu Scale measure was recorded as the difference in the angle between initial catch and a full range of motion, with larger angles denoting more severe spasticity. The Modified Ashworth Scale was shown to have acceptable reliability at the elbow and wrist.[33]

Process ability was the process skills component of the AMPS. This evaluates the child's ability to logically sequence, adapt to, and overcome obstacles to successfully complete a task[28] and is fundamentally a different construct to the motor component assessed by the AMPS. All measures used in the model were organized such that higher values represented higher levels of the latent concept they described.

Statistical analysis

Demographic characteristics of the sample were reported using means and standard deviations or frequency distributions for interval and ordinal variables respectively. SEM[40,41] was used to evaluate the model predicting ISC. Most indicators used in the model were ordinal, so a weighted least squares mean-variance adjusted estimator[42] was used as implemented in Mplus software.[43] Missing data were treated according to the Mplus default procedure for the weighted least squares mean-variance adjusted estimator.[44] Model fit was assessed using the χ^2 statistic divided by degrees of freedom, comparative fit index, the Tucker–Lewis Index, the root mean square error of approximation, and weighted root mean square residual. Typically used thresholds indicative of sufficient model fit were followed.[45,46] However, it is acknowledged that there is ongoing research about the best choice of fit indices as well as the suitability of predetermined fixed cut-offs for these indices,[47,48] particularly in small sample size models.[49] The reported fit indices should be viewed by readers collectively while determining the model fit. Although the sample size used in this study was substantial compared with other publications of children with CP,[50] it is smaller than the generally suggested limit of 200 cases for SEM.[41] At the same time, it is suggested in the literature that sample sizes exceeding 100 may be sufficient for models showing well-fitting latent measurement models.[51–53] Factoring small sample size, centile bootstrapped 95% confidence intervals (CIs) were also reported with 1000 bootstrap samples used.[54] Possible bias due to higher proportions of missing data in the 3-year-old subsample of children was evaluated by undertaking a sensitivity analysis running a model excluding ten 3-year-old participants. This was felt necessary because, other than sensory function in this age-group, there were relatively few missing data points in the other variables measured and this analysis was only undertaken to ensure the potential systematic error did not lead to an erroneous result.

We postulated that the exogenous variable of manual ability would influence ISC with the largest effect size; also, that sensory loss and spasticity would be negatively related to ISC with a similar magnitude of effect size. For process skills, age and intellect were felt to be the variables that would have a positive effect of similar magnitude.

RESULTS

Descriptive statistics for the measured variables can be seen in Table SI (online supporting information).

Direct effects

Direct effects of the model can be seen in Figure S1 (online supporting information). These were significant and positive between manual ability and ISC ($\beta=0.47$), and between process skills and ISC ($\beta=0.63$), suggesting that an increase in both concepts produces higher levels of ISC. Sensation had a significant positive direct effect on manual ability ($\beta=0.52$), and spasticity had a significant negative direct effect on manual ability ($\beta=-0.44$). Age had a small significant negative direct effect on manual ability ($\beta=-0.20$) and a significant direct positive effect on process skill ($\beta=0.53$), as did intellect ($\beta=0.33$) and, marginally, sensation ($\beta=0.33$, $p=0.057$). The model predicted a considerable proportion of variances in three endogenous concepts, with $R^2=0.90$ for ISC, $R^2=0.77$ for manual ability, and $R^2=0.61$ for process skills. Bootstrapped CIs reported in Table SII (online supporting information) concurred with the main analysis, and wide CIs were indicative of the sample size. Sensitivity analysis of excluding 3-year-old children reported in Figure S2 (online supporting information) and Table SII (online supporting information) matched the whole-sample results, with a possibly larger effect of sensation on process skills and manual ability on ISC.

Indirect effects

Table I presents standardized estimates of the indirect effects from sensory function, spasticity, age, and intelligence to ISC mediated by process skills and manual ability. There was a positive indirect effect for sensory function ($\beta=0.24$) and a negative effect ($\beta=-0.21$) for spasticity on manual ability. Age ($\beta=0.34$) positively indirectly influenced ISC, as did intellect ($\beta=0.21$), through their effect on process skills. There was also an indication that process skills ($\beta=0.21$, $p=0.085$) could be a mediator for the effect of sensation on ISC.

Model fit

The whole-sample results produced a satisfactory fit of the model with the data. Categorical estimator fit indices were as follows: the ratio of χ^2 to degrees of freedom was 1.48, while the comparative fit index and Tucker–Lewis Index were 0.99 and 0.98 respectively. Root mean square error of approximation was 0.07 with 90% CIs of 0.05 to 0.08. Weighted root mean square residual was 0.69. Corresponding statistics for the model excluding 3-year-old children were also acceptable (χ^2/degrees of freedom=1.38, comparative fit index=0.99, Tucker–Lewis Index=0.99, root mean square error of approximation=0.06 [90% CI 0.04–0.08], weighted root mean square residual=0.66). The

Table I: Indirect effects from sensory function, spasticity, age, and intelligence to independence in self-care (ISC) for 108 children with unilateral cerebral palsy recruited from a population register followed by results of sensitivity analysis excluding 3-year-olds

	n=108 children				n=98 children (excluding 3-y-olds)			
	Standardized estimate	Standard error	Two-tailed p	Bootstrapped 95% CI	Standardized estimate	Standard error	Two-tailed p	Bootstrapped 95% CI
Sensory function → process skills: ADLp → ISC	0.21	0.12	0.085	(−0.05 to 0.55)	0.28	0.18	0.122	(−0.05 to 0.66)
Sensory function → manual ability → ISC	0.24	0.09	0.007	(0.02–0.51)	0.34	0.14	0.016	(0.07–0.61)
Sum of above indirect effects of sensory function	0.46	0.16	0.003	(0.03–0.85)	0.62	0.25	0.013	(0.18–1.09)
Spasticity → process skills: ADLp → ISC	−0.08	0.11	0.446	(−0.34 to 0.1)	−0.07	0.14	0.595	(−0.47 to 0.22)
Spasticity → manual ability → ISC	−0.21	0.08	0.009	(−0.39 to −0.02)	−0.24	0.11	0.033	(−0.47 to −0.07)
Sum of above indirect effects of spasticity	−0.29	0.15	0.051	(−0.69 to −0.09)	−0.31	0.21	0.13	(−0.81 to 0.01)
Age → process skills: ADLp → ISC	0.34	0.08	<0.001	(0.16–0.47)	0.29	0.09	0.001	(0.12–0.44)
Age → manual ability → ISC	−0.09	0.05	0.057	(−0.21 to 0)	−0.13	0.06	0.033	(−0.31 to −0.02)
Sum of above indirect effects of age	0.24	0.09	0.007	(−0.01 to 0.47)	0.17	0.10	0.087	(−0.02–0.34)
Intelligence → process skills: ADLp → ISC	0.21	0.09	0.026	(0.06–0.4)	0.19	0.10	0.049	(0–0.5)
Intelligence → manual ability → ISC	0.07	0.06	0.195	(−0.02 to 0.28)	0.08	0.07	0.252	(0–0.3)
Sum of above indirect effects of intelligence	0.28	0.12	0.025	(0.12–0.63)	0.27	0.14	0.055	(0.11–0.69)

ADLp, process skills component of the Assessment of Motor and Process Skills measure.

p-values for the χ^2 test of model fit were found to be significant, which is not desirable, but the sensitivity of this fit index to the size of the model is a known limitation. However, the model purposely did not fix small paths to zero in pursuit of a better fitting model, to allow the CIs for these paths to be estimated factoring low statistical power due to our sample size.

DISCUSSION

The main findings of this study are that manual ability (muscle power and motor control) and process skills are the variables most strongly related to functional outcome as defined by ISC in children with unilateral CP. Traditionally there has been a greater emphasis on the treatment of the positive features of the upper motor neuron syndrome, such as spasticity, rather than on the negative features, such as muscle weakness.[37,55] The findings of our analysis indicate that muscle power and its key relation to manual ability is a more critical element to treat to improve ISC than spasticity in children with unilateral CP. However, given the effects of spasticity on function as defined in our model, and its effect on upper limb movement patterns,[56] spasticity should also be assessed and treated.

Hand function for the completion of self-care tasks is a complex entity that relies on cognitive ability,[14] with children learning to compensate for impairments, such as by using visual monitoring of the affected hand,[17] in task completion. Process skill is a cognitive function used to complete self-care tasks and, in the context of this study, indicates the degree to which the participant can use knowledge, organization, adaptation, and efficiency for task completion.[28] These skills relate directly to speed of information processing, which has been studied in childhood. In preterm birth, slowed processing speed was associated with motor impairment[57] and poorer executive functioning (problem-solving).[58] Motor learning theory suggests that motor skills can be learned implicitly, without an increase in knowledge about the skill, or explicitly, with knowledge used to build performance rules that guide motor performance.[59] In this theory, the process skills component impacts explicit learning and affects function,[21] consistent with our model. Moreover, the model supports the theory of implicit learning, through the influence on functional outcome of manual ability, sensation, and spasticity; and explicit learning, through the influence on functional outcome of age, process skills, sensation, and intelligence.[59]

The finding that sensory function directly influences manual ability significantly, with its indirect effect on ISC through manual ability and process skills, is novel. Disturbed sensory input from the affected hand of children with unilateral CP leads to reduced internal representation of the properties of objects, producing a reduction in

anticipatory control[17,60] and thus the ability to manipulate objects in the hand and to grasp effectively.[9] As sensation improves, so does manual ability, but only because sensation facilitates control as information is processed. This interplay between sensory function, manual ability, and process skills leading to changes in anticipatory control and influencing functional outcome is consistent with the model presented. Demonstrated in the model is that sensory function is critical to functional outcome, and overall a greater emphasis needs to be developed in clinical practice to record and potentially treat sensory function[61] and process skills in children with unilateral CP.

Age was a factor that was strongly and indirectly related to ISC through its direct effect on process skills, but it impacted function negatively through manual ability. Functional improvement in explicit motor learning was found to be correlated with age.[59,62] Proposed here is a model supporting this hypothesis through the process skills component. Studies also revealed age effects, with improvements in grip strength,[5] spontaneous hand use,[13] and grasping efficiency[20] over time. As children grow and develop, tasks generally increase in complexity and differences in ability compared with typically developing peers may become more apparent in the presence of processing difficulties. This provides further credibility to the model presented, with the inclusion of processing skills allowing better adaptation for more efficient movement of the upper limb. In contrast, the negative effect of age on manual ability is also explained in the literature. Manual ability as defined in the model relied on assessments of symmetry of movement, supination ability and range, and muscle power generation. With age, contractures across the elbow, wrist, and pronators of the upper limb can lead to a reduction in function, with surgical release procedures allowing for improvements.[6]

Now that a model of the relative contributions of upper limb impairments is demonstrated, other findings suggested in the literature can be explained using the model and give further context to the findings. For example, spasticity can result in altered posture and movement patterns that affect the speed and efficiency of movement. Gordon and Duff[9] argue that spasticity may only influence functional outcome owing to its effect on motor performance on certain aspects of a task (such as grip force adaptation) but not others (such as anticipatory control). This supports our findings of a direct effect of spasticity on manual ability, but not a direct effect of spasticity on process skills or functional outcome.

Strengths of this study included recruitment from a population-based cohort of children with unilateral CP experiencing a wide range of impairment. Children were assessed in their home environment for the functional measures, in keeping with the ICF model. Relatively quick clinical measures of impairment level function were used to define their limitations, having wider applicability in clinical medicine.[63] Another strength of the study was the use of SEM with an estimator suitable for largely ordinal data along with SEM capabilities of modelling measurement errors and testing the indirect effects. Study weaknesses included the presence of missing data and the small numbers of participants, considered to be only just adequate for this type of analysis, particularly in light of the ordinal measures used extensively in clinical testing. Missing data in this study represented the youngest of the unilateral CP population. These weaknesses were addressed by using bootstrapping and subanalysis excluding ten 3-year-old participants. The validity of the AMPS has been confirmed in typically developing children except for the motor scale in very young children,[64] with a higher than acceptable percentage of misfitting items, further highlighting limitations for this study in assessing children as young as 3 years. Another major weakness was that the measures for motor control have not, until recently,[65] been extensively validated, and no data reporting the reliability of the measures used currently exists. As is the case with any SEM models proposed, cross-validation of our results is required, preferably with a larger sample size. This is particularly important in light of using ordinal measures, which, although clinically functional, are not the most robust from a perspective of measurement quality.

In conclusion, the results of this analysis show that children with unilateral CP, while expected to perform at peer levels, have significant impairments that affect their ISC. This study demonstrates that, to improve ISC for children with unilateral CP, the modalities of muscle power and sensory function should be prioritized over spasticity and must be managed effectively in the context of the child's age and cognitive abilities. Further studies should build on this model and bring into the framework reliable measures of motor control and expand on the cognitive measures undertaken. Future models could also measure important determinants of functional ability such as developmental disregard,[66] mirror movements,[67] and bimanual coordination,[68] as well as other constructs of the ICF such as personal and environmental factors, to continue to develop insights into improving outcomes for this group of children.

SUPPORTING INFORMATION
The following additional material may be found online:

Table SI: Measured variables and the results for 108 children with unilateral cerebral palsy

Table SII: Standardized structural equation modelling coefficients

Figure S1: Structural equation model for the standardized solution obtained from measures of 108 children with unilateral cerebral palsy.

Figure S2: Sensitivity analysis for the standardized solution obtained from measures of 98 children with unilateral cerebral palsy.

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RESUMEN

COMPROMISO DE EXTREMIDADES SUPERIORES, HABILIDADES DE PROCESAMIENTO Y PRONÓSTICO DE NIÑOS CON PARÁLISIS CEREBRAL UNILATERAL

OBJETIVO Evaluar la relación entre el daño de las extremidades superiores y la independencia en el autocuidado de niños con parálisis cerebral unilateral.

METODO Ciento ocho niños con parálisis cerebral unilateral (46 mujeres, 62 varones; media de edad 8 años y 7 meses, desviación estándar 3 años y 9 meses) fueron reclutados de un registro poblacional. Se evaluó la fuerza muscular, espasticidad, sensibilidad, control motor y habilidades de procesamiento. Como resultado funcional para la independencia en el autocuidado se usaron modelos de ecuación estructural.

RESULTADOS El modelo mostro un adecuado ajuste y explicó el 90% de la varianza en la independencia en el autocuidado. Los efectos directos entre la habilidad manual y el autocuidado (β=0,47), y las habilidades de procesamiento y el autocuidado (β=0,63) fueron significativos. La sensibilidad tuvo un efecto positivo indirecto sobre el autocuidado a través de la habilidad manual (β=0,24 y un efecto positivo, pero marginalmente no significativo a través de las habilidades de procesamiento (β=0,21, error estándar 95% con un intervalo de confianza de -0,05 a 0,55). La espasticidad tuvo un efecto indirecto negativo significativo en el autocuidado, a través de su efecto en la habilidad manual (β=$-$0,21). La edad tuvo un efecto positivo significativo indirecto sobre el autocuidado, al igual que en el intelecto, a través de su efecto sobre las habilidades de procesamiento (β=0,34 y 0,21 respectivamente).

INTERPRETACIÓN La independencia en el autocuidado depende del compromiso de las extremidades superiores y de las habilidades de procesamiento. La sensibilidad influencia el autocuidado a través del efecto sobre la habilidad manual y las habilidades de procesamiento. Ambas, la sensibilidad y las habilidades de procesamiento requieren evaluación adicional para ayudar a la independencia de autocuidado en niños con parálisis cerebral unilateral.

RESUMO

DEFICIÊNCIAS NO MEMBRO SUPERIOR, HABILIDADES DE PROCESSAMENTO, E DESFECHO EM CRIANÇAS COM PARALISIA CEREBRAL UNILATERAL

OBJETIVO Examinar as relações entre deficiências no membro superior e independência no auto-cuidado (IAC) em crianças com paralisia cerebral (PC).

MÉTODO Cento e oito crianças com PC unilateral (46 do sexo feminino, 62 do sexo masculino; média de idade 8a 7m, DP 3a 9m) recrutadas a partir de um registro populacional foram avaliadas quanto a força muscular, espasticidade, sensação, controle motor, e habilidades de processamento do membro superior, e quanto a IAC como resultado funcional, usando modelamento de equação estrutural.

RESULTADOS O modelo mostrou bons índices de adequação e explicou 90% da variância na IAC. Efeitos diretos foram significativos entre a capacidade manual e IAC (β=0,47), e habilidades de processamento e IAC (β=0,63). A sensação teve efeito significativo positivo indireto na IAC por meio da capacidade manual (β=0,24) e efeito positivo indireto mas marginalmente não-significativo por meio das habilidades de processamento (β=0,21, intervalo de confiança bootstrapped a 95% - 0,05 a 0,55). A espasticidade teve efeito significativo negativo indireto na IAC por meio do seu efeito na capacidade manual (β=$-$0,21). A idade teve efeito positivo significativo indireto na AAC, assim como o intelecto, por meio do seu efeito nas capacidades de processamento (β=0,34 e 0,21 respectivamente).

INTERPRETAÇÃO A IAC é afetada pelas deficiências do membro superior e pela habilidade de processamento. A sensação infuencia a IAC por meio de seus efeitos nas habiildades manuais e de processamento. Tanto a sensação quanto as habilidades de processamento requerem maior avaliação para facilitar a IAC em crianças com PC unilateral.