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ORIGINAL ARTICLE

Arm hand skilled performance in persons with a cervical spinal cord injury—long-term follow-up

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Study design: Retrospective cohort study.

Objective: To assess development of arm hand skilled performance (AHSP) during and after in-patient rehabilitation in persons with cervical spinal cord injury (CSCI) and to determine factors that influence the outcome.

Setting: Eight rehabilitation centres in the Netherlands with specialised spinal cord injury departments.

Methods: AHSP was assessed using the Van Lieshout test (VLT) in persons admitted with recent CSCI. Assessment was carried out at the beginning (t1), after 3 months (t2), at the end (t3) of in-patient rehabilitation, and 1 and 5 years thereafter (t4, t5). Multilevel regression analysis was performed to determine development of AHSP and associations between AHSP and age, gender, motor completeness, lesion level (high or low CSCI), motor scores of upper extremity (MSUE), and pain in the tested arm.

Results: Fifty-five participants were included with mean age 38 years (range 18–64). There were 73% male, 80% had high CSCI (C3–C6) and 69% had motor complete lesion. Scores of VLT improved significantly during in-patient rehabilitation (mean: $t1=25$; $t3=33$) ($P=0.005$), scores remained unchanged at 1 year ($t4=32$) and 5 years ($t5=32$) ($P=0.903$) after in-patient rehabilitation. Motor completeness, MSUE and pain were significantly related to the VLT score ($P<0.001$, $P<0.001$, $P=0.015$, respectively). Age, gender and lesion level had no significant relationship.

Conclusion: AHSP improved during in-patient rehabilitation. It was then stable during the next 5 years after discharge. Persons with an incomplete lesion, high MSUE and no pain in the tested arm perform best on the VLT.

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Keywords: arm hand skilled performance; Van Lieshout test; cervical spinal cord injury; long-term outcome

INTRODUCTION

The worldwide incidence of spinal cord injury varies between 10.4 and 83 per year per million inhabitants. A significant number of this, almost one-third, is reported to be tetraplegic.[1] The level of impairment of arm hand function and (in)dependence in self-care relates to the level and completeness of the cervical spinal cord injury (CSCI).[2,3] Improved arm hand function is positively related to improvement of quality of life.[2,4] It is also stated that improving arm hand function has the highest priority in persons with chronic CSCI.[2,5]

Only few studies in the medical literature describe long-term outcome of arm hand function in persons with CSCI at activity level.[6–10] The modified Barthel index and quadriplegia index of function are used as outcome measures in four of these studies.[6–9] Although they are activity level instruments, they involve more skills than just arm hand function. Harvey *et al.*[10] used an activities of daily living test; however, the test was not validated before use. In addition, in the past studies meaning of the term arm hand function was unclear. It did not define whether it was related to the level of body function or activity, according to the International Classification of Functioning, Disability and Health (ICF) model.[11] To clarify this difference, Spooren *et al.*[12] introduced the term 'arm hand skilled performance' (AHSP) which accurately describes the functional possibilities of the arm and hand. The Van Lieshout test (VLT) used in this study, is designed to objectively quantify the quality of movement of the upper extremity at the basic activities level in persons with CSCI.[12,13] Spooren *et al.*[8] measured the AHSP using the VLT. They demonstrated that AHSP improves significantly during in-patient rehabilitation and then remains stable up to one year after discharge. There is a distinct paucity of studies in the medical literature describing long-term outcome of arm hand function.

The aim of the present study was to describe long-term outcome of AHSP in persons with CSCI. We studied the natural progression of AHSP using the VLT beyond one year after discharge. We also investigated association between the variables and the outcome. This may have implications for the duration of rehabilitation programmes for the tetraplegic upper limb and timing of reconstructive interventions.

MATERIALS AND METHODS

Participants

Data used for the present study was collected during a national research programme 'Physical strain, Work Capacity and Mechanisms of Restoration of Mobility in the Rehabilitation of Persons with Spinal Cord Injuries'. Eight rehabilitation centres in the Netherlands participated in the study. This was a prospective cohort study in which persons with an acute spinal cord injury admitted to these centres were followed from the onset of the active rehabilitation process to discharge from the centre and then follow-up measurements were carried out at 1 and 5 years after discharge.

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The criteria for the data to be included the present study were: persons with an acute CSCI (including thoracic 1-level), aged between 18 and 65 years and had no progressive disease. Data were excluded if persons had severe additional neurological, orthopaedic or rheumatologic diseases, or psychological problems that might interfere with the AHSP or if they did not understand the Dutch language well.

Design

Data were available of all persons who started their rehabilitation from the onset of their CSCI. For the study, five specific measurement moments were chosen to assess AHSP: t1—at the start of active rehabilitation (it was termed as active rehabilitation because then the participants were able to sit consecutively for 3 h in a wheelchair, were free of their halo or corset and were able to start activity training); t2—at 3 months after the start; t3—at discharge from the rehabilitation centre; t4—one year after discharge and t5—five years after discharge. The assessment protocol was approved by the medical ethics committees of all of the participating rehabilitation centres. Informed consent was given by all subjects.

Measurements

From the prospective cohort study the following data were available: age at the time of injury, gender and motor scores. Motor scores for each participant were determined on the basis of neurological assessment according to the 'International Standards for neurological and functional Classification of Spinal Cord Injury' (ISNCSCI) provided by the American Spinal Injury Association (ASIA).[14]

For the purpose of the present study a differentiation was made between motor complete (ASIA Impairment Scale (AIS) A and B) and motor incomplete lesions (AIS C and D). Furthermore a differentiation was also made between high CSCI (lesion level C3 to C6) and low CSCI (lesion level C7 to Th1).

The research version of the Van Lieshout test (VLT-SV, short version) was used to assess AHSP. This instrument was developed to objectively quantify the quality of AHSP in persons with a CSCI.[12,13] According to the ICF model, it relates to the domain of (basic) activities.[13] The VLT-SV includes 10 of the original 19 tasks. The possible ways of performing each task are described in six hierarchical levels, resulting in a score from 5 for the highest level of performance to 0 when the task cannot be performed at all.[13] The total score can range from 0 to 50. The best arm hand for each task was tested; as a result, in some persons a different arm hand was tested at different assessment moments and also within one assessment for different tasks.

The criterion validity, the inter-rater reliability as well as the internal consistency reliability of the VLT-SV is very good (Spearman's $r=0.87$–0.90, ICC$=0.98$–0.99, Cronbach's $\alpha=0.88$–0.94, respectively). The VLT-SV is sensitive to detect changes in AHSP during rehabilitation in persons with CSCI.[12,13]

Pain in the tested arm was evaluated by asking if subjects experienced pain in the upper extremity. The patients were asked at the time of the tests to indicate the presence or absence of pain in the tested arm.

Based on the available medical literature, following determinants were chosen out of the database for the purpose of analysing relationship between the AHSP and influencing factors: age,[15] gender,[16] motor score of upper extremity,[17] completeness of CSCI,[17] and high vs low cervical lesion.[18] Pain as an influencing factor on the outcome measure has rarely been studied. It was thought that it would be interesting to study the influence of pain on AHSP and hence it was also included.

Data analysis

At least three measurements needed to have been completed by each participant to be considered for analysis. Multilevel regression analysis (MLwiN)[19] was used for statistical purposes. This method enables us to reach meaningful conclusions over the entire follow-up period inspite of missing data points including t1. As mentioned previously, the independent variables for this analysis were age at the time of injury, gender, motor complete or incomplete CSCI, total motor scores of the upper extremity, high (C3–C6) or low (C7–T1) CSCI level and pain in the tested arm.

The total scores of the VLT-SV were modelled over time using time periods as categorical variables (dummy), with the moment of discharge (t3) as reference, that is, Δt1t3, Δt2t3, Δt3t4 and Δt3t5. The regression coefficient for a time period (for example, start to discharge; 3 months after start to discharge) describes the change of AHSP over that time period. An additional regression analysis was performed using the assessment 5 years after discharge (t5) as a reference, that is, Δt4t5, to investigate the change in AHSP between 1 and 5 years after discharge. Statistical analysis programme SPSS for Windows (version 11.5) was used for this analysis.

Further, longitudinal relationships between the VLT-SV scores and the independent variables were investigated. All independent variables were measured during each assessment, except age at time of injury and gender (only collected at t1). The variables were added one by one to the basic model with the time dummies only. Independent variables with $P\leqslant 0.1$ were included in a subsequent multivariate model with a backward selection procedure, excluding non-significant determinants ($P>0.05$) to create the final multivariate model.

RESULTS

The mean age of the participants was 38 years (s.d. 12.93) with a range from 18 to 64 years. Other characteristics of the participants are described in Table 1.

The mean VLT-SV scores over time are presented in Table 2. The mean score increased significantly during in-patient rehabilitation from 25 at t1 to 33 at t3 (Δt1t3, $P<0.005$), but did not significantly change after in-patient rehabilitation (t4 = 32 and t5 = 32)

Table 1 Patient characteristics

	n	%
Total participants	55	100
Male	40	73
Female	15	27
C3–C6	49	89
C7–Th1	6	11
AIS AB	38	69
AIS CD	17	31
	Number of participants n (%)	*Time since injury Mean ± s.d. in weeks*
t1	47 (86)	14 ± 11.27
t2	45 (82)	31 ± 12.10
t3	54 (98)	58 ± 27.60
t4	42 (76)	117 ± 30.22
t5	29 (53)	352 ± 32.46

Values are *n* or %; mean ± s.d. in weeks.

Table 2 The basic multilevel regression model for the total score of the VLT-SV

VLT total score t3 as reference			*VLT total score t5 as reference*		
	β (s.e.)	P		*β (s.e.)*	P
Intercept	32.618 (2.850)		Intercept	31.655 (3.256)	
Δt1t3	−7.941 (2.839)	0.005	Δt1t5	−6.977 (3.270)	0.033
Δt2t3	−4.685 (2.533)	0.064	Δt2t5	−3.722 (2.997)	0.214
Δt3t4	−0.591 (2.582)	0.819	Δt3t5	0.963 (2.899)	0.740
Δt3t5	−0.963 (2.899)	0.740	Δt4t5	0.372 (3.037)	0.903

Abbreviation: VLT, Van Lieshout test.
Time dummies included only.
Values are the regression coefficient (β) with the s.e. An increase in VLT score is indicated by a negative sign during in-patient rehabilitation, Δt1t3 and Δt2t3. A decrease in VLT score after in-patient rehabilitation, Δt3t4 and Δt3t5, is indicated by a negative sign.

Table 3 Final multivariate regression model for the total score of the VLT-SV

	VLT total score	
	β (s.e.)	P
Intercept	2.074 (2.569)	
Δt1t3	−0.518 (1.739)	0.766
Δt2t3	−1.239 (1.350)	0.359
Δt3t4	0.474 (1.379)	0.731
Δt3t5	10.258 (2.816)	<0.001
Completeness	−2.966 (1.161)	<0.001
Motor score UE	1.115 (0.059)	<0.001
Pain tested arm	−2.595 (1.068)	0.015
Lesion level	NS	
Age	NS	
Gender	NS	

Abbreviations: NS, independent variable was proven not significant in previous analyses and thus not entered into this model; UE, upper extremity; VLT, Van Lieshout test.
Values are the regression coefficient (β) with the s.e. for the model after backward elimination. The regression coefficients represent the change in outcome associated with an increase of the independent variable of 1 unit.
Completeness: incomplete = 0; complete = 1.
Lesion level: C3–C6 = 0; C7–T1 = 1.
Pain in tested arm: not present = 0; present = 1.

(Δt3t5, $P = 0.740$; Δt4t5, $P = 0.903$). Table 3 shows the results of the final multilevel regression model. After the backward selection procedure, three independent variables, namely, incomplete lesion ($P < 0.001$), high motor score upper extremity ($P < 0.001$) and no pain in the tested arm ($P = 0.015$) were found to be significantly related to the total score of the VLT-SV. The relationship was positive, that is, an incomplete lesion adds 3.0 extra points, no pain in the tested arm adds 2.6 points and every point of the MSUE adds 1.1 point to the total VLT-SV score. Lesion level, that is, high versus low, age and gender were not significantly related to the total score.

DISCUSSION

The aim of this study was to describe long-term results of AHSP assessed using the VLT-SV. The main findings were:

1. The score of the VLT-SV changed significantly during in-patient rehabilitation (in accordance with Spooren *et al.*[8]) but did not change significantly thereafter (up to 5 years after discharge).
2. Amongst the six independent variables tested, incomplete lesion, high MSUE and no pain in the tested arm were positively related to a higher score. Lesion level, that is, high versus low, age and gender did not have a significant relationship to the total score.

Arm hand skilled performance

For multilevel analysis t3 (end of in-patient rehabilitation) was chosen to enable comparison between the changes during the in-patient period and during the post-rehabilitation period. The in-patient period in the Netherlands is long compared with the other parts of the world.[8] In this study, the mean time since injury at t3 was about one year, t3 was unique for every patient representing reaching a plateau for motor performances since the time of injury. This is subscribed by the fact that the AHSP did not significantly improve after in-patient rehabilitation and remained stable in the years thereafter. This result coincides with the results of the earlier research.[6,8] It is known that most spontaneous neurological recovery occurs in the first 3–9 months after injury.[17,18] The period of in-patient rehabilitation in this study, during which improvement in AHSP occurred coincides with the period of most neurological recovery. As lengths of in-patient rehabilitation are or inclined to be much shorter in various parts of the world (including the Netherlands), clinicians have to be aware that plateau for the motor skills may not have been reached at the time of discharge and continuing training after discharge from in-patient rehabilitation and follow-up could be useful.[8] Although Kirshblum and Fawcett[17,18] have indicated that neurological recovery may continue until 18 months after injury, this study shows that AHSP does not improve after 1 year after injury. Usually consideration for reconstructive surgery is postponed until after the neurological recovery is complete, that is, for about 2 years after the injury. However, results of this study show that there is no further improvement in AHSP after 1 year after the injury and hence reconstructive surgery for improvement of arm hand function could be considered and performed after 1 year after the date of injury.

Independent variables

We studied six independent variables. Three variables, namely, incomplete lesion, high motor score upper extremity and no pain in tested arm, turned out to be statistically relevant in improving the VLT score. Several studies also conclude that an incomplete lesion and a high motor score of the upper extremity have a better functional prognosis.[8,17,18] Pain is infrequently investigated. It could be that pain in the tested arm leads to diminished functioning due to avoidance or diminished motivation. We did take pain into consideration; however, it was not studied in detail. Hence, besides indicating the influence of pain in AHSP we cannot make any further comments. In future, the relationship between pain and AHSP needs to be studied in greater detail.

Surprisingly, the lesion level was not significantly related to the outcome. Looking back, there were only six subjects with low-level CSCI and out of these, three were determined by sensory level. This number is too low to reach statistical significance.

Methodological considerations

There are some methodological limitations to this study. First, only 29 of the 55 participants performed the VLT-SV at t5. Loss-to-follow-up and missing values is a common problem encountered in the longitudinal studies, this was true for this study as well. Use of multilevel regression analysis was an attempt to minimise this problem.

Second, there is a ceiling effect in test performance. In this study, subjects with spinal cord lesions from C3 to T1 were included. It is well known that in subjects with a high initial MSUE, the incidence of arm hand function problems is lower.

Last, the best arm hand was tested during measurement chosen by the patient. However, 24 subjects used the same hand throughout all the tests. Sixteen subjects out of the 25 subjects who completed both t4 and t5 used the same hand on both occasions. One might argue that the results of measuring the same arm hand are more accurate. However, the VLT is placed at the activity level according to the ICF model.[13,20] This implies that it measures the functional abilities of the subject using his or her best arm hand in performing daily skills. This best arm could be different at different measurement moments or different for different tasks. It was thought to be important to obtain the best functional result instead of measuring the improvement of AHSP in one specific arm hand.

CONCLUSION

This is the first study evaluating long-term outcome of AHSP at activity level in patients with CSCI.

One can conclude from this study that the AHSP measured by the VLT-SV improves significantly during in-patient rehabilitation, the average duration of this period was 58 weeks, after that period AHSP did not change significantly. Continuation of rehabilitation programme to improve AHSP may not be necessary after 1 year and arm hand reconstructive surgery could be considered then on.

Significant relationship exists between VLT-SV scores and completeness of lesion, MSUE and pain in the tested arm. Lesion level, that is, high versus low, age and gender do not have a significant relationship to the total score.

In previous studies in the literature, pain has not received much attention. We have shown that there exists a relationship between AHSP and the presence of pain. Future studies should examine this relationship in greater detail as well as whether effective pain management could improve performance.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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