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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

The interaction between trunk, shoulder, and upper limb dysfunctions during reaching in a post-stroke population

Ann-Sophie Franssen
Justine Nobels

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij neurologische aandoeningen

PROMOTOR :
Prof. dr. Peter FEYS

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dr. Ilse LAMERS

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Acknowledgement

Throughout the writing of this master's thesis we received a considerable amount of support and assistance from a lot of people. We would like to start off by thanking our promoter Prof. Dr. Peter Feys for giving us the opportunity to work on this topic and for his valuable feedback. Furthermore, we would like to especially acknowledge our co promotor Dr. Ilse Lamers and mentor Dra. Joke Raats who guided us throughout the process of completing our master's thesis. Their assistance and feedback during the past two years was of great value and helped to take our work to a higher level.

We are very grateful to the rehabilitation centers of Jessa Hospital Campus St. Ursula, Ziekenhuis Oost Limburg (ZOL) Campus St. Barbara, and Noorderhart Rehabilitation & MS Center Pelt for giving us the opportunity to continue testing participants in these difficult and uncertain COVID-19 times. Without the help, time, and effort of the physiotherapists recruiting eligible participants, we would not have been able to carry out this study. In addition, we would like to thank all of the patients for their time and willingness to participate in our study. Lastly, we highly appreciate the interest and time of our family, friends and anyone else to read our master's thesis.

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Research context

Neurological rehabilitation is defined by the World Health Organization as a complex process that assists individuals who experience disability to optimize functioning in interaction with their environment (World Health Organization, 2020). During this process the patient, their family, and many disciplines have to work actively together in order to help the patient cope with their life after the neurological injury (Barnes, 2003). Goals, that are important to the patient, are set with the aim of working towards being as independent as possible in performing everyday activities and enabling participation (World Health Organization, 2020). Currently, it is estimated that around one billion people worldwide suffer from a neurological disorder. As the global burden of neurological disorders, measured by DALY's, appears to be very high and keeps increasing, the need for rehabilitation also continues to increase (Bertolote et al., 2006; GBD 2016 Neurology Collaborators, 2019). This outlines the importance of developing and investigating effective treatment strategies. Our thesis, including stroke patients, can be situated in the neurological domain of rehabilitation.

A stroke or Cerebro Vascular Accident (CVA) is an acute focal injury to the central nervous system. It has a vascular cause since the blood vessels in the brain are affected. A stroke can occur due to ischemia, insufficient blood supply, or due to a hemorrhage, a bleeding (Hankey, 2017; Sacco et al., 2013). This disturbance in the blood perfusion causes necrosis of the brain tissue. The areas surrounding the damaged part and connected to it have the risk to be endangered as well. Due to this damage, neurological complaints like unilateral weakness, numbness, visual loss, altered speech etc., can occur (Hankey, 2017; Hankey & Blacker, 2015). Many stroke patients experience upper limb (UL) disability. In approximately 70% of the stroke population, sensorimotor disturbances appear in the contralateral arm (Meyer et al., 2014). These disturbances can vary from a flaccid arm to coordination problems. Other common UL manifestations include changes in muscle tone, joint laxity and impaired motor control (Hatem et al., 2016). They often cause persistent deficits in the UL function. Kwakkel et al. (2003) stated that only 12% of individuals with severe stroke regains complete function of the paretic arm at six months, while 62% does not regain any ability to reach and grasp despite intensive physiotherapy. This limits the use of the affected arm and negatively impacts the independent functioning of the patient (Langhorne et al., 2009; Raghavan, 2015). Reaching and grasping, however, does not only require a good UL function. It requires the control of many degrees of freedom of different joints, so that a desired trajectory and interjoint coordination can be performed (Bernstein, 1967; Kelso et al., 1991; Ma & Feldman, 1995; Mussa Ivaldi et al., 1988). Levin et al. (2016) suggested that the trunk is also an integral part of the reaching pattern. Similar to the recruitment pattern in healthy individuals, the onset of the trunk movement after stroke occurs before or simultaneously with the arm movement (Levin et al., 2002; Michaelsen et al., 2006). Despite that fact, excessive trunk displacement is a common compensation in patients with chronic stroke (Cirstea & Levin, 2000; Levin et al., 2002). This is often combined with excessive shoulder movements, like horizontal abduction (Levin et al., 2016). These alternative movement patterns of the trunk and shoulder are specifically seen to compensate for the lack of movement in the hemiplegic arm (Levin et al., 2016; Mandon et al., 2016; Shaikh et al., 2014). In recent years, research to this interaction between the trunk, shoulder, and upper limb has increased. In this master's thesis, the aim was to understand if and how these different joints interact with each other during reaching. This is necessary to provide an appropriate treatment to regain the lost functionality and independence. Therefore a comprehensive assessment of the trunk, upper limb and shoulder was needed.

This study is part of the PhD of Dra. Joke Raats, "A comprehensive assessment of the trunk, scapula and upper limb in neurological patients. Reliability, validity and interrelatedness." Consequently, this work was supervised by Dra. Joke Raats as mentor, Dr. Ilse Lamers as co promoter and Prof. Dr. Peter Feys as promoter. As part of her PhD, Dra. Joke Raats conducted a similar study in patients with Multiple Sclerosis (MS). Further, this duo master's thesis is a continuation of the study that Eline Voets (E.V.) and Maik Tysiak (M.T.) started last year. Their test results were combined with the results collected this year for the data-analysis.

During the summer break of 2020, both students started with the data collection by testing patients at the Jessa Rehabilitation Center St. Ursula. Unfortunately, this could no longer be continued during the academic year due to the pandemic of COVID-19. From February till March 2021 A.F. had the opportunity to continue the data collection at Ziekenhuis Oost Limburg (ZOL) Campus St. Barbara during her internship. Further, both students prepared the data for the analysis and started writing the different parts of this master's thesis. J.N. performed the statistical analysis, except for the mediation analyses, while A.F. wrote the acknowledgement, research context, and methods. The abstract, introduction, statistical analysis, results and discussion were written by both students.

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The interaction between trunk, shoulder, and upper limb dysfunctions during reaching in a post-stroke population

Ann-Sophie Franssen & Justine Nobels

Master's dissertation submitted in order to obtain the academic degree of Master in Rehabilitation Sciences and Physiotherapy in Neurological Disorders

Promoter: Prof. Dr. Peter Feys

Co promoter: Dr. Ilse Lamers

Mentor: Dra. Joke Raats

Faculty of Rehabilitation Sciences

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1. Abstract

Background: Reaching is a functional activity that requires coordinated movements of the trunk and both the proximal and distal upper extremity. Unfortunately, sensorimotor impairments caused by a stroke can impact this function causing people to lose their independence and functionality. To be able to provide an appropriate treatment, it is necessary to understand how these impairments interact with each other.

Objective: The aim of this study was to determine the interrelatedness between the trunk, upper limb and shoulder function during reaching post-stroke.

Methods: *Participants.* Twenty-three subacute and eight chronic stroke patients (58% male; age $\pm$ 64.52 years) with a mild stroke (NIHSS $\pm$ 2.27) were recruited from August 2019 till March 2021 in three rehabilitation centers. *Measurements.* The trunk, shoulder, and upper limb were evaluated using the Trunk Impairment Scale (TIS), Clinical Scapular Protocol (ClinScaP) and Box and Block Test (BBT) in order to evaluate their influence on the reaching performance, measured by the Reaching Performance Scale (RPS). A mediation analysis was performed to investigate the interrelatedness.

Results: Positive indirect relations were found between the RPS and the TIS and ClinScaP through the BBT. The Sobel's test values for the TIS with the RPS-Close Target, RPS-Far Target, and RPS-Total were respectively 0.008, 0.004, and 0.005. The Sobel's test values between the ClinScaP and RPS-Close Target, RPS-Far Target, and RPS-Total were respectively 0.01, 0.006, and 0.007.

Conclusion: The upper limb function is the key element in the reaching pattern and can indirectly be influenced by trunk and shoulder dysfunctions that occur after stroke. Appropriate treatments for these dysfunctions should be incorporated early in the process to maximize arm function recovery and reaching.

Keywords: stroke, upper limb, shoulder, trunk, reaching

2. Introduction

Each year, 17 million people worldwide experience a first-time stroke (Feigin et al., 2014). Consequently, it is recognized as the major cause of disability as it is responsible for 42.2% of the global neurological Disability Adjusted Life Years (DALY's) (Collaborators, 2019). A stroke, causing sensorimotor impairments, could impact a person's activities of daily life (ADL) and independence (Santos et al., 2018). Up to 70% of stroke survivors experience upper limb impairments like muscle weakness, contractures, changes in muscle tone, joint laxity, and impaired motor control (Allison et al., 2016; Hatem et al., 2016; Meyer et al., 2014). Initially, a flaccid paralysis of the contralesional arm sets in due to the nerve damage that arises after stroke. This prevents the muscles from receiving any signal from the brain, whether or not the corticospinal tract is still intact. While the upper limb function is recovering from this flaccid stage of stroke, abnormal and stereotypical movement patterns start to appear as a result of the redevelopment of basic synergies (Brunnstrom, 1970; Twitchell, 1951). Signe Brunnstrom (1970) attributes these abnormal patterns to the incomplete repair of the connections of the muscles. As a certain muscle is activated, it stimulates the cooperative muscles to start responding as well. The brain fails, due to the damage of the stroke, to send the right inhibitory or excitatory signals to the right muscles (O'Sullivan et al., 2014). Because of this, two principal synergies can be observed after stroke: the extensor synergy and flexor synergy. The extensor synergy typically consists of shoulder extension and adduction, combined with elbow extension, forearm pronation and wrist flexion (Cirstea & Levin, 2000). While the flexor synergy consists of shoulder flexion and abduction combined with elbow flexion, forearm supination and wrist extension. The flexor synergy appears when, for example, a patient tries to reach forward. Due to the activation of the shoulder flexors, the muscles that perform shoulder abduction and external rotation, elbow flexion, and wrist supination get stimulated as well (Alt Murphy et al., 2011; Cirstea & Levin, 2000; Ma et al., 2017). These pathological stereotypical coupling movements of the arm complicate voluntary movements like reaching and are observed as a phenotype of the loss of interjoint coordination after stroke (Schwarz et al., 2020). This causes the patient to be severely limited in the ability to adapt movements to varying tasks or environmental demands (O'Sullivan et al., 2014).

Reaching has been defined as the voluntary positioning of the hand at or near a desired target (Carr & Shepherd, 2011). It requires coordinated movements of the trunk, shoulder, and elbow to obtain the desired trajectory and interjoint coordination (Bernstein, 1967; Kaminski et al., 1995; Levin et al., 2016; Mussa Ivaldi et al., 1988; Subramanian et al., 2010). Due to the lack of interjoint coordination after stroke, patients struggle to perform voluntary movements and use compensatory strategies instead. Levin et al. (2002) found that hemiparetic individuals recruit their trunk earlier or more when moving towards targets placed close to the body in comparison with healthy individuals. The trunk also showed more forward displacement, asymmetric rotation, and lateral shift to the paretic side. Overall, evidence shows that the poorer the motor recovery, the more alternative trunk movements are used to compensate for the deficits in active joint ranges of their hemiparetic arm (Levin et al., 2016). In addition to the trunk, the shoulder also exhibits altered movements. For instance, excessive forward trunk displacement is often combined with more shoulder abduction to compensate for the reduced elbow extension (Liu et al., 2013). This strategy in particular is more effective in patients with mild UL impairments, because they have preserved some degree of motor adaptability (Levin et al., 2016). These compensatory movement strategies arise, because the damaged system seeks the most effective movement strategy available to compensate for the diminished control of more distal movements (Michaelsen et al., 2004).

All these factors impact the reaching performance of a patient which in turns limits the capability to perform ADL tasks. Reaching performance in a stroke population is therefore a topic that is highly investigated. This study however is the first to specifically investigate the interrelatedness of the impairments of the shoulder, upper limb, and trunk during reaching in a post-stroke population. The purpose is to identify the influence of the impairments in order to give a better understanding of the interjoint relationships and their part in reaching deficits. When these interjoint relations are more understood, a more specific rehabilitation can be carried out by the therapist.

3. Methods

This cross-sectional study was conducted from August 2019 till March 2021 in three rehabilitation centers in Belgium: Jessa Rehabilitation Center St. Ursula, Ziekenhuis Oost Limburg (ZOL) Campus St. Barbara, and Noorderhart Rehabilitation & MS Center Pelt. The study was approved by the ethics committee of all aforementioned centers and the University of Hasselt before recruitment started. It also complied with all the ethical principles for medical research involving human subjects of the WMA Declaration of Helsinki. The informed consent was given to the participants prior to testing so that one could read through the document. On the first day of testing, the participants were re-informed verbally to make sure everything was clear. Afterwards they were asked to sign the informed consent.

3.1. Participants

Stroke patients were recruited by a physiotherapist in the institutions using a purposive sampling. Patients were eligible if they met the following criteria: (1) > 18 years old, (2) first-ever single, unilateral stroke, (3) without apraxia or hemi-spatial neglect, (4) able to understand and execute the test instructions, (5) able to sit on a chair with low back support for 10 minutes and (6) able to move at least 1 out of 3 joints of the affected upper limb (wrist, elbow or shoulder) with a Medical Research Council score 3. Patients were excluded if they had any other medical condition interfering with the upper limb or trunk function (e.g. orthopedic or rheumatoid impairment), a perceived pain of > 4/10 in one of the upper limbs scored by the Visual Analogue Scale, or a severe cognitive or visual impairment. The in- and exclusion criteria are summarized in **Table 1**.

Table 1 – Selection criteria

Inclusion criteria	Exclusion criteria
• Age: > 18 years old • First-ever single, unilateral (ischemic or hemorrhagic) stroke • No apraxia or hemi-spatial neglect • Able to understand and execute the test instructions • Able to sit on a chair with low back support for 10 minutes • Able to move at least 1 out of 3 joints of the affected UL (wrist, elbow or shoulder): MRC 3	• Other medical conditions interfering with the UL or trunk function (orthopedic or rheumatoid impairment) • Perceived pain in one of the UL: VAS > 4/10 • Severe cognitive or visual deficits

Abbreviations: UL, upper limb; MRC, Medical Research Council; VAS, Visual Analogue Scale.

3.2. Experimental Procedure

Measurements were conducted by four independent assessors (A.F., J.N., M.T. & E.V.) at two different test sessions with a duration of one hour each. The two sessions were required to take place within one week and at the same time of the day. All tests and questionnaires were executed randomly in order to avoid an order bias.

Table 2 – Outcome measures according the ICF

Body function	Activities	Participation
• **Clinical Scapular Protocol (ClinScaP)** • **Trunk Impairment Scale (TIS)** • Active and Passive Range of Motion (AROM/PROM) • Modified Ashworth Scale (MAS) • Brunnström Fugl Meyer (BFM-UE) • Maximal hand grip strength (JAMAR) • National Institutes of Health Stroke Scale (NIHSS)	• **Reaching Performance Scale (RPS)** • **Box and Block Test (BBT)** • Action Research Arm Test (ARAT) • Nine Hole Peg Test (NHPT) • 10 Meter Walk Test (10MWT) • Modified Rankin Scale (MRS) • Manual Ability Measure-36 (MAM-36) • Edinburgh Handedness Inventory (EHI) • Motor Activity Log (MAL)	/

Note: Primary outcome measures in **bold**.

3.2.1. Descriptive outcome measures

In order to describe the characteristics of the included stroke population, the following data were first collected from each patient: age, gender, time since stroke, side of stroke, medication intake, and comorbidities. These patient characteristics were collected during the first session through the medical record obtained by the referring neurologist. Furthermore, twelve descriptive outcome measures were used. An overview of these outcomes is provided in **Table 2** where they are classified according to the International Classification of Functioning, Disability and Health (ICF) (Salter et al., 2013).

Body structures and function

National Institutes of Health Stroke Scale (NIHSS) (Brott et al., 1989). The NIHSS was used to assess stroke severity. This test comprises the following aspects: consciousness, ability to respond to questions and execute simple commands, deviation of gaze and hemianopsia, facial palsy, motor function of UL and LL, limb ataxia, sensibility, aphasia and dysarthria, and visual spatial neglect or anosognosia. It was scored on a total of 42 points with higher scores reflecting greater severity (Anemaet, 2002; Kwah & Diong, 2014; Salter et al., 2013).

Active and Passive Range of Motion (AROM/PROM). The active and passive ROM of both arms were measured using a goniometer. The following movements were assessed in degrees: shoulder flexion, elbow extension and wrist dorsal and palmar flexion.

Brunnström Fugl Meyer (BFM-UE) (Fugl-Meyer et al., 1975). For this study only the upper extremity subscale of the motor function domain (BME-UE) was applied. In total, the BFM-UE consists of 33 items divided into the following categories: (A) reflex activity, synergies and volitional motion of the shoulder, arm and forearm, (B) wrist stability and motion, (C) hand motion/grasps and (D) coordination/speed. The items are each scored on a 3-point ordinal scale between 0 and 2 (0 = cannot perform, 1 = performs partially and 2 = performs fully). Eventually, a score at 66 was administered (Gladstone et al., 2002; Platz, Pinkowski, van Wijck, & Johnson, 2005; See et al., 2013). The Brunnström Fugl-Meyer is a reliable and valid test and is considered as a core measure for stroke patients (Kwakkel et al., 2017).

Modified Ashworth Scale (MAS) (Ashworth, 1964). The spasticity of the shoulder adductors, elbow flexors, wrist flexors and finger flexors was assessed using the Modified Ashworth Scale. First, the passive ROM was evaluated to check if movements of the joints were pain free. Then, the spasticity of the muscle groups was evaluated by repeating the same movement at the same speed five times. The highest resistance was scored from 0 (no elevated muscle tone) to 4 (immovable) (Bohannon & Smith, 1987; Gregson et al., 1999).

Maximal hand grip strength (JAMAR). The JAMAR® Hydraulic Handheld Dynamometer (Model J00105) was used to measure the maximal isometric grip force in kilograms. The position of the hand grip handle was adjustable for different hand sizes. The middle phalanx of the middle finger of each participant had to form an exact angle of 90°. Further, the arm was held in 90° elbow flexion with the forearm in a neutral position. The participants had to squeeze the handheld dynamometer as hard as they could. The dominant hand was always assessed first. Three trials per arm were taken with a rest interval of 30 seconds after each trial. The mean score of the trials was calculated (Amaral et al., 2012; Schaubert & Bohannon, 2005).

Activities

Action Research Arm Test (ARAT) (Carroll, 1965; Lyle, 1981). The ARAT was used to observe coordination, dexterity and functioning of the upper extremity. Nineteen items divided into the following sub items were measured: grasp, grip, pinch and gross movement. Both hands were tested separately with the non-affected side always first. For each of these items the time to execute the task was timed with a chronometer watch. Subsequently, a score between 0 (no movement) and 3 (movement performed normally) was assigned based on the execution and time the participant had achieved. A higher score indicated a better performance with 57 points being the maximum score (Platz, Pinkowski, van Wijck, & Johnson, 2005).

Nine Hole Peg Test (NHPT) (Kellor et al., 1971). During the NHPT the patients were asked to place nine pegs into a plastic block with holes and then remove them again. The intention was to do this as quickly as possible. If a peg fell onto the table, the patient had to pick it up themselves. If a peg fell onto the ground, the peg was picked up for them by the assessor. Both the dominant and non-dominant hand were tested twice consecutively with the dominant hand always starting first. All of the trials were timed using a chronometer watch. If it took the patient more than five minutes to complete the trial, the trial was terminated. The fastest trial of both hands was used in the analysis. The purpose of this test was to measure the fine manual dexterity (Fischer et al., 2001; Salter et al., 2013).

10 Meter Walk Test (10MWT) (Collen et al., 1990). During the 10MWT the participants were asked to walk at a comfortable speed. Over the 10 meter distance their walking speed was measured in meters per second. If a walking aid was needed, it was reported at the test form. The test was repeated three times and a mean walking speed was calculated afterwards.

Modified Rankin Scale (MRS) (Rankin, 1957). The Modified Rankin Scale, also known as the Modified Rankin Handicap Scale, is a test in which the degree of dependence on others during the performance of activities is administered. A single score on a 6-point ordinal scale between 0 (no symptoms) and 5 (severe handicap) was assigned (Salter et al., 2013; van Swieten et al., 1988).

Manual Ability Measure-36 (MAM-36) (Chen & Bode, 2010; Chen et al., 2005). The perceived difficulty that the patient may experience during the performance of unilateral and bilateral ADL-tasks was measured with the MAM-36. In the form of a semi-structured interview, 36 activities were rated between 1 (unable to perform) and 4 (easy to perform). A score of 0 was only given if the participant never performed the activity (Chen et al., 2014). To avoid frustration in participants that suffered from aphasia or severe dysarthria, a paper with the meaning of the scores was used so that they could point to their answer on the paper. Their answers were written down on the test form by the assessor.

Motor Activity Log (MAL) (van der Lee et al., 2004). During a semi-structured interview the participants were asked how often (Scale A: frequency) and how good (Scale B: performance) their affected arm participated during the surveyed activities. Both scales were scored on a 6-point scale.

Edinburgh Handedness Inventory (EHI) (Oldfield, 1971). This test was used to determine the hand dominance of a person during everyday activities. The participants were asked with which hand they perform the ten different activities or manipulate the specified objects. A Laterality Quotient value was calculated to interpret the handedness by the following formula: (R-L)/(R+L) x 100. A value of less than -40 indicated left-handedness, between -40 and +40 ambidexterity and more than +40 right-handedness.

3.2.2. Primary outcome measures

In total, four primary outcome measures were used for the comprehensive assessment of the trunk, upper limb, and shoulder to investigate their interrelatedness during reaching. An overview of these outcomes is also provided in **Table 2**.

Body structures and function

Trunk Impairment Scale (TIS) (Verheyden et al., 2004). The static and dynamic sitting balance as well as the trunk coordination were assessed based on the seventeen items of the Trunk Impairment Scale by Verheyden et al. The items were scored on a 2-, 3- or 4-point ordinal scale and the test was performed in a standardized manner. For example, the patients needed to sit on the edge of a treatment table with their knees in a position of 90° without wearing shoes and socks. They had three chances to perform each item of which the highest score was noted. Eventually, a maximum score of 23 could be earned by the participants. A high score on the TIS meant a better trunk function without compensation strategies. Concerning the psychometric properties, the Trunk Impairment Scale showed a good to excellent test-retest reliability (ICC = 0.87-.99) and inter-rater reliability (ICC = 0.85-0.99). The internal consistency measured by Cronbach's alpha for the total TIS was nearly excellent (α = 0.89). They also investigated the content validity of the Trunk Impairment Scale. Further, an excellent correlation between the Barthel Index and TIS (r = 0.86) was shown for the construct validity. For the concurrent validity, an excellent correlation between the Trunk Control Test and TIS (r = 0.83) was shown (Verheyden et al., 2004; Verheyden et al., 2007). Lastly, the three subscales and total Trunk Impairment Scale showed a significant ability to discriminate between stroke patients and healthy controls (p <0.0001) (Verheyden et al., 2005; Verheyden et al., 2007).

Clinical Scapular Protocol (ClinScaP) (De Baets et al., 2016). The protocol consists of five tests: (1) observation of tilting and winging during rest and movement, (2) shoulder girdle position tests (Pectoralis minor index, acromion index and scapular distance test), (3) scapular lateral rotation measurement, (4) maximal humeral elevation and (5) medial rotation test. The execution of the ClinScaP can be observed in **Fig. 1**. Test 1 and 5 were scored on an ordinal scale between 0 and 2. The height of each of the participants was asked for test 2 to calculate the Pectoralis minor index and acromion index. A measuring tape and sliding carpenter were used to measure the distance between the indicated reference points of test 2. Further, an inclinometer was required for test 3 and a goniometer for test 4. De Baets et al. also checked the reliability of the ClinScaP in their study. They demonstrated very high ICC's for tests 2, 3, and 4 except for the Pectoralis minor index. A substantial inter-rater reliability was shown for test 1, observation at rest, and test 5. Also, an almost perfect inter-rater reliability was shown for observation during movement of test 1. Eventually, the decision was made to only incorporate test 4 of the ClinScaP in the mediation analyses, because it showed the highest level of measurement quality and clinical utility.

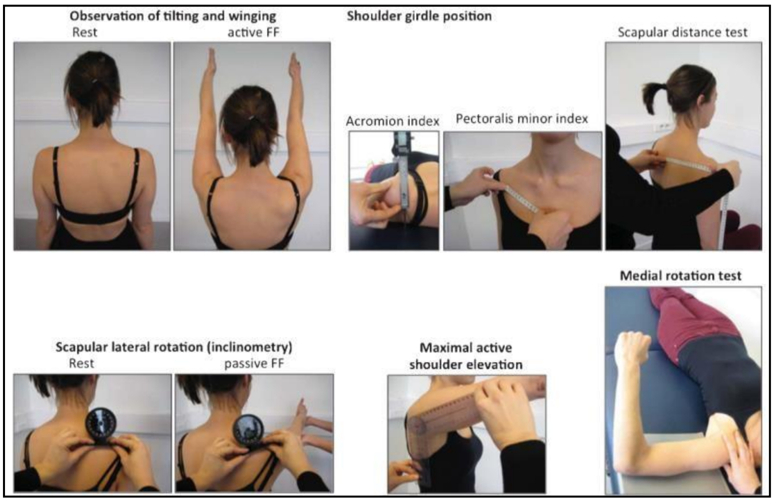

Fig. 1 - Clinical Scapular Protocol (De Baets et al., 2016)

Activities

Reaching Performance Scale (RPS) (Levin et al., 2004). The RPS has the purpose of assessing and identifying compensatory movements during a reach-to-grasp task in people post-stroke. The focus is mainly on the transport phase of reaching, from the participant starting the movement until the cone being grabbed. During the test, the participant had to reach six times for a close and far target. The execution was recorded by a frontal and sagittal camera perpendicular to the patient. More detailed technical instructions can be observed in **Fig. 2**. Afterwards, six components were scored by two independent assessors on a 4-point scale (0-3) based on these recordings: trunk displacement, movement smoothness, shoulder movements, elbow movements, prehension and global score. A maximum score of 18 could be obtained for the far and close target separately. In order to keep the test standardized it was always performed with the same height difference between the table and chair (~30cm) and by using the same low-back support chair for every subject. In exceptional cases, the test was performed from the wheelchair. The height different was preserved. Regarding the psychometric aspects, the RPS shows an excellent inter-rater reliability (r_{close}= 0.84 and r_{far}= 0.89) and intra-rater reliability (r_{close}= 0.80-0.95 and r_{far}= 0.83-0.94) for both targets. Correlations between the RPS and the Chedoke McMaster Stroke Assessment, TEMPA and grip force were examined to study the concurrent validity. Moderate correlations were found between the RPS and grip force (r_{close}= 0.60 and r_{far}= 0.63) whereas excellent correlations were found with the Chedoke McMaster Stroke Assessment (r_{close}= 0.92-0.95 and r_{far}= 0.90-0.93) and TEMPA (r_{close}= -0.84 and r_{far}= -0.88). The Reaching Performance Scale was also able to discriminate between different levels of upper extremity impairments in stroke patients in both the close and far target ($p < 0.0001$)) (Levin et al., 2004).

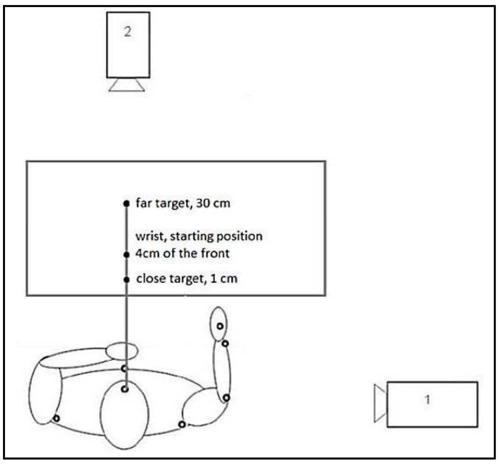

Fig. 2 - Technical instructions of the Reaching Performance Scale

Box and Block Test (BBT) (Mathiowetz et al., 1985). This performance-based measure of gross manual dexterity was administered once for the dominant hand and once for the non-dominant hand. The participant was given one minute to move as many blocks as possible from one compartment to the other compartment of the box. If the participant took two blocks simultaneously, it was counted as one. It was not allowed to throw the blocks over the partition without crossing it with at least a part of the fingers (Salter et al., 2013). Literature shows an excellent test-retest reliability (r = 0.98; ICC = 0.89-0.96) and interrater reliability (r = 0.99) in subjects with an upper limb impairment due to stroke. Further, the BBT has an excellent convergent validity with the ARAT (r = 0.95), BFM (r = 0.92), and Hemispheric Stroke Scale (r = -0.67). (Chen et al., 2009; Mathiowetz et al., 1985; Platz, Pinkowski, van Wijck, Kim, et al., 2005). Adequate to excellent correlations were found for the concurrent validity between the BBT and the NHPT (r = -0.71), ARAT (r = 0.64), BFM (r = 0.35), MAL-AOU (r = 0.49), MAL-QOM (r = 0.52), and SIS (r = 0.52) (Lin et al., 2010).

3.3. Statistical analysis

Statistical analyses were performed using JMP® Pro 15.2.0 (466311) (SAS Institute Inc., Cary, NC, USA). A level of statistical significance of $\alpha < 0.05$ was set. The normality of data was assessed using the Shapiro-Wilk test. Further, the Variance Inflation Factor (VIF) value was set at 5 to check for multicollinearity and the Durbin-Watson test was used to assess autocorrelation in the data. Since the distribution of the data was skewed, our results are presented as median [interquartile range]. Mediation analyses with linear regression were performed to investigate the associations between the reaching performance and the trunk, upper limb, and shoulder dysfunctions of stroke patients. The following hypothesis was used: H_0 = there is no relationship between X, the independent variable, and Y, the dependent variable. Only the direct effect (c') and the indirect effect (ab) with a mediator variable (M) were considered in the interpretation of the mediation analyses (**Fig. 3**) (Agler & De Boeck, 2017).

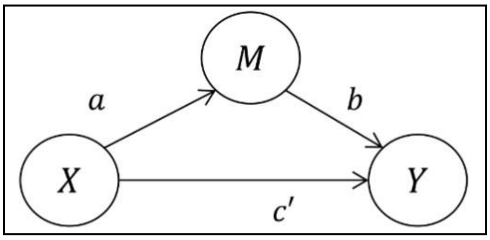

Fig. 3 - Effect of X and Y including a mediation (Agler & De Boeck, 2017)

4. Results

4.1. Patient characteristics

A total of 33 participants (19 men and 14 women) with a mean age of 64.52 ± 15.66 years were enrolled in this study. According to the NIHSS, the majority of the patients had a mild stroke (Adams et al., 1999). Fifteen patients showed a mild upper extremity impairment, another 15 had a moderate-mild impairment, while only three patients had a severe-moderate impairment (Woytowicz et al., 2017). Further, there were 23 patients in the subacute recovery phase (<6 months post-stroke) and eight in the chronic recovery phase (>6 months post-stroke). Their **handgrip force** was measured with a handheld dynamometer and the paretic hand showed a median force of 13kg which is up to 51% lower compared to healthy older adults of the same age category (Desrosiers et al., 1995). Seven patients were unable to perform or complete the **10MWT**. None of the other patients could be classified under household ambulation, but 11 patients were a limited community ambulator, and 16 patients a full community ambulator (Perry et al., 1995). Most of the subjects had no spasticity as they scored zero on the **MAS** of all the tested muscle groups. When spasticity was present, it was mainly seen in the elbow flexors. The results of all descriptive outcome measures can be found in **Table 4**. It should be noted that the medical records of patients 20 and 21 were missing, causing the data (age, time since stroke and side of stroke) to be incomplete.

Table 4 – Descriptive measures	
Participants (n)	33
Age (mean years ± SD)	64.52 ± 15.66
Gender (M/F), n (%)	19/14, 58/42
Time since stroke (mean days ± SD)	174.81 ± 316.07
Side of stroke (L/R), n (%)	15/18, 45/55
Hand dominance prior to stroke (L/R/A)	2/30/1
NIHSS (0-42)	2 [0.5,4]
Active ROM (°)	
Shoulder Flexion (°)	130 [96, 142]
Elbow Extension (°)	0 [0, 1]
Dorsiflexion (°)	42 [30.5, 52]
Palmar flexion (°)	50 [39, 69]

Abbreviations: M, male; F, female; L, left; R, right; A, ambidexter; NIHSS, National Institutes of Health Stroke Scale; ROM, Range of Motion. Data are presented as median [IQR] unless otherwise stated.

Table 4 – Descriptive measures (continued)	
Passive ROM (°)	
Shoulder Flexion (°)	141 [120, 155]
Elbow Extension (°)	0 [0, 0]
Dorsiflexion (°)	52 [42, 63.5]
Plantarflexion (°)	64 [49.5, 80]
BFM-UE (0-66)	50 [40, 60]
ARAT (0-57)	47 [36, 54]
Handgrip strength (kg)	13 [6.58, 19.92]
NHPT (peg/s)	0.18 [0.04, 0.25]
10MWT (s)	10.29 [7.25, 12.99]
mRS (0-5)	2 [1, 4]
MAM-36 (0-144)	119 [94.5, 132]
EHI	100 [86.67,100]
MAL-TOT (0-5)	1.46 [0.89, 3.33]
MAL-AOU (0-5)	1.52 [0.96, 3.25]
MAL-QOM (0-5)	1.48 [0.88, 3.1]
MFIS (0-84)	30.5 [14.5, 42.75]

	0	**1**	**1+**	**2**	**2+**	**3**
MAS (0-3)						
Shoulder Adductors	26	4	0	2	0	0
Elbow Flexors	18	10	1	4	0	0
Wrist Plantarflexors	28	1	2	2	0	0
Finger Flexors	28	2	1	1	0	1

	Household ambulation (<0.4m/s)	**Limited community ambulation (0.4-0.8m/s)**	**Full community ambulation (>0.8m/s)**
10MWT	0	11	16

Abbreviations: ROM, Range of Motion; BFM-UE, Brunnström Fugl-Meyer Assessment – Upper Extremity; NHPT, Nine Hole Peg Test; BBT, Box and Block Test; mRS, modified Rankin Scale; MAM-36, Manual Ability Measure-36; EHI, Edinburgh Handedness Inventory; MAL-TOT, Motor Activity Log – Total score; MAL-AOU, Motor Activity Log – Amount of Use; MAL-QOM, Motor Activity Log – Quality of Movement; MFIS, Modified Fatigue Index Scale; MAS, Modified Ashworth Scale; 10MWT, 10-Meter Walk Test.

Data are presented as median [IQR] unless otherwise stated.

4.2. Group results of the primary measures

The median score of the total **RPS** was 32 with an interquartile range from 23.5 to 36. So, overall the participants scored very well as twelve participants scored the maximum of 36 on the RPS-Total, and 13 and 14 patients scored the maximum score of 18 on the close and far target respectively. The sum of the scores of the subitems are presented in **Appendix – Table 1**. The **TIS** showed a median score of 17 with an IQR of 15 to 19.6. A score of 20 is used as a cut-off value. This means that eight participants had a normal trunk function. The participants scored the best at the static subscale as 23 participants scored the highest possible score. The dynamic and coordination subscales contained more demanding tasks and, respectively, only 6 and 4 participants reached the maximum score. Further, the participants scored a median score of 26 on the BBT. This score is remarkably lower than the normal values of ± 68 blocks/minute for right-handed male and ± 76 blocks/minute for female between 65 and 69 years old (Mathiowetz et al., 1985). In **Table 6**, all of the scores on the different test items of the **ClinScaP** can be found. In this study, test 4 was the most important. The median maximal active humeral elevation of test 4 was 130° with a IQR of 96 to 142. This means that the majority of the patients were able to reach far above 90° shoulder elevation. An overview of the results of the primary outcome measures are listed in **Table 6**.

Table 6 – Primary Outcome Measures	
RPS-Total	32 [23.5, 36]
RPS-Close Target	17 [12.5, 18]
RPS-Far Target	15 [12, 18]
TIS-Total	17 [15, 19.5]
TIS-Static	7 [6, 7]
TIS-Dynamic	8 [6.5, 9]
TIS-Coordination	2 [2, 4]
BBT	26 [17.5, 37]

Abbreviations: RPS-Total, Reaching Performance Scale Total Score; RPS-Close Target, Reaching Performance Scale Close Target; RPS-Far Target, Reaching Performance Scale Far Target; TIS-Total, Trunk Impairment Scale Total Score; TIS-Static, Static Sitting Balance Subscale of the Trunk Impairment Scale; TIS-Dynamic, Dynamic Sitting Balance Subscale of the Trunk Impairment Scale; TIS-Coordination; Coordination Subscale of the Trunk Impairment Scale; BBT, Box and Block Test.

Data are presented as median [IQR] unless otherwise stated.

Table 6 – Primary Outcome Measures (continued)	
ClinScaP	
TEST 2 – ACR-INDEX	0.04 [0.03, 0.05]
TEST 2 – PECT-INDEX	0.1 [0.09, 0.10]
TEST 2 – SCAP-DIST	1.56 [1.48, 1.72]
TEST 3 – Rest	0 [-7, 0]
TEST 3 – 30°	2 [-0.5, 8]
TEST 3 – 60°	8 [2, 13]
TEST 3 – 90°	17 [10.5, 21]
TEST 3 – 120°	29 [19.5, 33.5]
TEST 4	130 [96, 142]

	N T/W	T/W	T+W	N AT/SM	AT/SM	AT+SM
ClinScaP						
TEST 1 – R	19	12	2			
TEST 1 – M	21	10	2			
TEST 5				12	19	2

Abbreviations: ClinScaP, Clinical Scapular Protocol; TEST 2, Shoulder girdle position tests; ACR-INDEX, Acromion index; PECT-INDEX, Pectoralis Minor index; ScapDist, Scapular Distance Test; TEST 3, Scapular lateral rotation measurement in rest, 30°, 60°, 90° & 120°; TEST 4, Maximal active humeral elevation; TEST 1, Observation of tilting and winging during Rest (R) and Movement (M); TEST 5, Medial Rotation Test; N T/W, No Tilting or Winging; T/W, Tilting or Winging; T+W, Tilting and Winging; N AT/SM, No Anterior Humeral Translation or Scapular Movement; AT/SM, Anterior Humeral Translation or Scapular Movement; AT+SM, Anterior Humeral Translation and Scapular Movement.

Data are presented as median [IQR] unless otherwise stated.

4.3. Association models based on mediation analyses

In total, nine association models were created to investigate whether trunk, shoulder, and upper limb dysfunctions directly or indirectly influence reaching post-stroke. Therefore, associations between the Trunk Impairment Scale, Box and Block Test, and test 4 of the Clinical Scapular Protocol (now referred to as 'Shoulder') and their influence on the Reaching Performance Scale were explored (**Fig. 4)**. Our results did not reveal any direct relationship between the trunk or shoulder and reaching, while the upper limb was consistently positively correlated with reaching. However, six models did show a significant indirect effect. They revealed that both trunk and shoulder impairments indirectly affect reaching for an object that is near and far away through the upper limb. In other words, shoulder and trunk impairments influence the functioning of the upper limb which in turn affects the reaching performance. This can be seen in **Fig. 4** as the TIS and RPS-Close Target (Sobel's test of 0.008), RPS-Far Target (Sobel's test of 0.004) and RPS-Total (Sobel's test of 0.005) showed a positive indirect relation via the BBT, respectively in models 2, 5, and 8. Also a positive indirect association was observed between the Shoulder and RPS-Close Target (Sobel's test of 0.01), RPS-Far Target (Sobel's test of 0.006) and RPS-Total (Sobel's test of 0.007) via the BBT in models 3, 6, and 9. A more detailed overview of the standardized values and p-values can be found in the **Appendix – Table 2**.

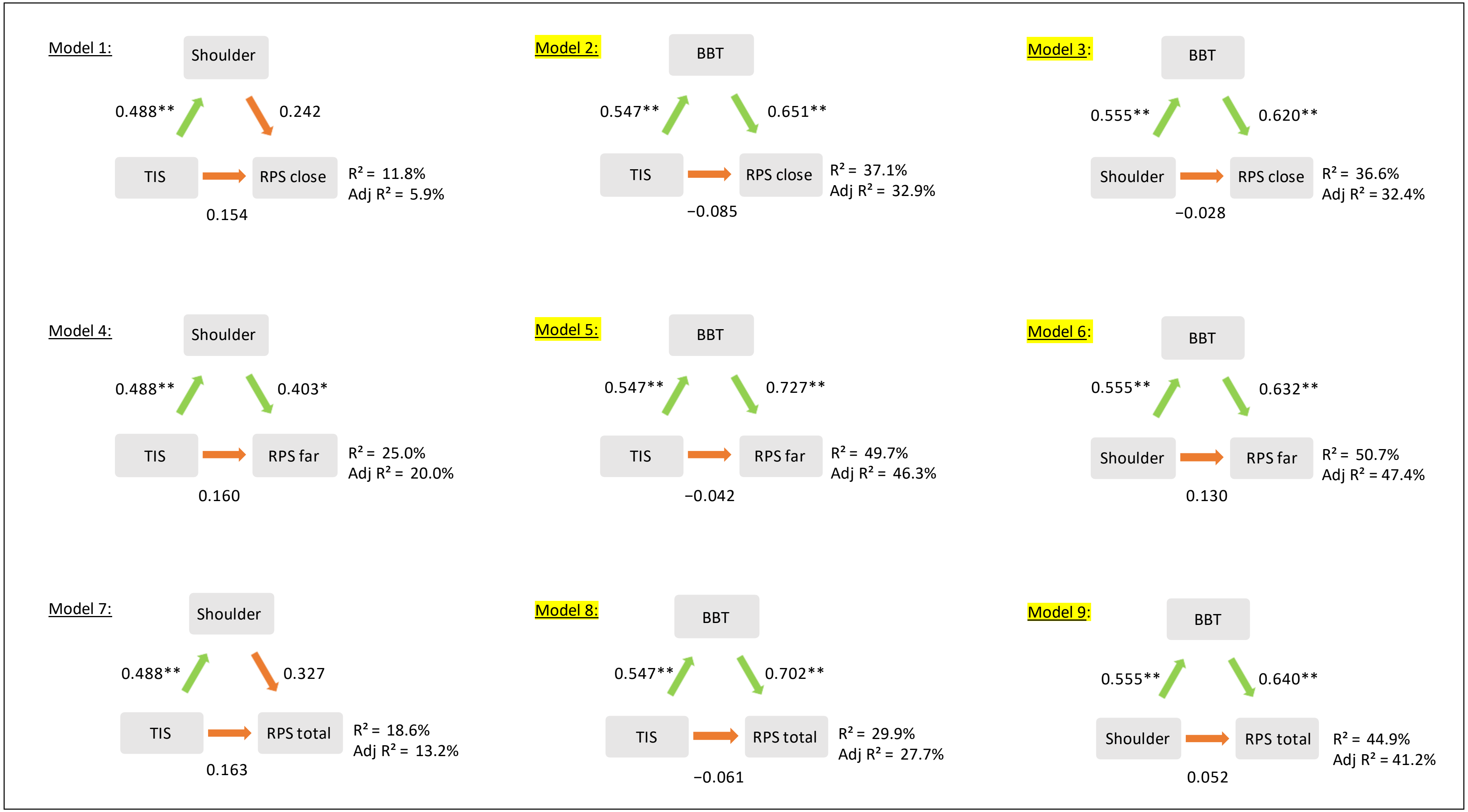

Fig. 4 - Association models
** p < 0.05; ** p < 0.01; yellow marking = significant Sobel's test.*

5. Discussion

The upper limb, shoulder, and trunk of stroke patients were assessed comprehensively by using the Box and Block Test, Clinical Scapular Protocol and Trunk Impairment Scale. This was done in order to investigate the influence of their functioning on the reaching pattern, measured by the Reaching Performance Scale. Regarding the primary measure of the upper limb, multiple options were first considered and discussed. The Action Research Arm Test, Brunnström Fugl-Meyer Assessment and Box and Block Test are all three recommended, because they demonstrated the highest level of measurement quality and clinical utility in individuals after stroke (Alt Murphy et al., 2015; Pohl et al., 2020). The ARAT was primarily selected, because it is a key measure for the upper limb in a post-stroke population (Kwakkel et al., 2017; Pohl et al., 2020). Although it provides a more comprehensive, activity-based overview of the arm function based on its grasp, grip, pinch and gross movement items, it is important to note that during the execution of the ARAT, reaching above shoulder height is asked. The ARAT seems to include both the upper limb and shoulder and was therefore chosen not to include this outcome measure in the further analyses. The upper extremity part of the Brunnström Fugl-Meyer was also considered. This assessment tool provides both distal and proximal information about the upper limb. The BFM-UE gives a better idea about the actual motor functioning of the arm, since it measures reflex activity, synergies, volitional arm movements, muscle force against resistance and dysmetria/tremor. Since the BFM also evaluates different parts of the shoulder function, it was decided to not use it either. Unlike the ARAT and BFM-UE, reaching above shoulder height is not required during the execution of the BBT. It is rather a quick and easy assessment tool that measures gross manual dexterity. It, therefore, seemed to be an acceptable primary outcome measure for the upper limb to answer our research question.

Overall, this study suggested that the upper limb is the key element during reaching after stroke. Besides being the only component that consistently correlated with reaching, the trunk and shoulder impairments also appeared to indirectly affect reaching for an object that is near and far away through the upper limb. Current literature seems to agree that elbow extension, shoulder flexion and shoulder horizontal adduction are the three main factors that are necessary to reach the endpoint during reaching (Cirstea & Levin, 2000; Michaelsen et al., 2004; Tomita et al., 2017). Elbow extension in particular is related to and important for the functional use of the hemiparetic arm (Massie et al., 2011). Beebe et al. (2008), on the other hand, stated that the AROM of the shoulder flexion explains 88% of the variance in the hand function early after stroke. Further, they found that 61% of the variance in hand function can be explained by the individuation of the joints. Individuation is defined as "the ability to make isolated motions of individual joints or body segments"(Shumway-Cook & Woollacott, 2007; Zackowski et al., 2004). Thus, those who presented a greater AROM were better in isolating movements of the different joints. The same correlation between shoulder motion and hand function was found in subjects with chronic hemiparesis (Lang & Beebe, 2007). These results showed that the loss of isolated movement control of the shoulder and elbow contributed to the loss of distal functions. In other words, it appears that the hand function highly relies on the ability to move the shoulder (Kapandji, 1981). It is, therefore, important that efforts are made to improve shoulder motion during rehabilitation to ensure a better hand function. Other studies found that the interjoint coordination between the shoulder and elbow is disrupted after stroke (Cirstea et al., 2003; Levin et al., 2016). In healthy individuals, the reaching movement starts by flexing the elbow followed by a combination of elbow flexion, shoulder horizontal adduction and shoulder flexion. Then the shoulder moves alone, further to horizontal adduction followed by the extension of the elbow and shoulder flexion. The reaching movement ends with a maximal elbow extension to let the hand reach the endpoint (Cirstea & Levin, 2000). This strong coupling between shoulder and elbow movements may be affected by the presence of abnormal synergies that arise after a stroke (Levin et al., 2016). Depending on the severity of the stroke, variations are found in the reaching strategy. For instance, in patients with mild stroke, it was found that the coupling of the shoulder and elbow coordination was preserved. They were able to easily adapt their reaching strategy depending on the placement of the target (ipsilateral, contralateral and central target). Unlike mild stroke, patients with moderate-to-severe stroke had difficulties to move their upper limb out of the abnormal flexor synergy causing the inability to adapt the reaching strategy (Levin et al., 2016; Shaikh et al., 2014). This was characterized by the use of less elbow extension and shoulder horizontal adduction (Cirstea et al., 2003; Collins et al., 2018). They had to use compensation strategies, like more forward trunk displacement and excessive shoulder horizontal abduction, to reach the target (Cirstea & Levin, 2000; Cirstea et al., 2003; Levin et al., 2016). This explains the relationship between the shoulder and upper limb and indirect correlations with reaching that were found in this study.

Postural stability of the trunk is necessary to be present during upper limb movements to support distal motion of the elbow and hand joints (Kaminski et al., 1995). Our results showed that a poor outcome on the TIS impacts the outcome on the BBT. In other words, if the trunk fails to provide postural stability due to dysfunctions in balance or coordination, than the upper limb will experience difficulties during movements like reaching. Another study found that the TIS scores were significantly correlated with the BFM-UE score ($r = 0.62$, $p < 0.001$). This suggests that patients with a lower TIS score were more likely to present a worse upper limb function (Kong & Ratha Krishnan, 2021). A good trunk performance seems to be important during voluntary movements of the extremities e.g. reaching (Verheyden et al., 2006). On the one hand, selective movements of the trunk ensure the maintenance of an upright posture during reaching, by keeping the center of mass within the base of support (Kong & Ratha Krishnan, 2021). On the other hand, the trunk is also an integral part of the reaching pattern as the onset of the trunk movement occurs before or simultaneously with the arm movement (Levin et al., 2002; Michaelsen et al., 2006). Despite these facts, excessive trunk displacement is a common compensation in patients with chronic stroke to compensate for the lack of movement in the hemiplegic arm (Cirstea & Levin, 2000; Levin et al., 2016; Levin et al., 2002; Mandon et al., 2016; Shaikh et al., 2014). Michaelsen et al. (2001) investigated the influence of these trunk compensations on the reaching ability in chronic hemiparetic individuals. By restricting the trunk, they observed the presence of a more ‘normal’ reaching pattern. Thus, it is possible that the normal patterns of movement coordination may not be entirely lost after stroke (Michaelsen et al., 2001). It, therefore, seems important that to maximize arm recovery after stroke, appropriate treatments for the trunk performance should also be incorporated early in the rehabilitation process.

5.1. Study strengths and limitations

5.1.1. Limitations

A first limitation in this study is the use of the original TIS. For the first item of this test, subjects need to be able to sit 10 seconds without arm and back support. Verheyden & Kersten (2010) removed this item from the test as it created a large ceiling effect. Namely, 90% of the subjects scored a maximum score of 2 on this item. In our study, all of the included patients scored maximum on this item, since it was a requirement that the patients could sit for 10 minutes with low-back support. Because of this, the subjects are more located on the top end of the scale, which makes it possible that the effect of the TIS and de RPS is smaller than in a more heterogenous population. A second limitation is that the psychometric values of the ClinScaP and RPS are questionable. Overall, the ClinScaP showed a substantial test-retest reliability, inter-rater reliability, and discriminant validity of most items. However, there are still unknown or not proven to be sufficient psychometric properties (De Baets et al., 2016). Since there are no other clinical tests available that solely investigate the shoulder complex in stroke patients and it showed a high level of measurement quality, it was chosen to still use the ClinScaP. Further, although the RPS has shown to be a valid and reliable assessment tool, it should be interpreted carefully. Since the population that was tested was only a small sample size of a non-presentative group (younger than usual stroke survivors), the results were only preliminary according to Levin et al. (2004). Lastly, our findings can't be generalized to other reaching tasks due to kinematic redundancy and task specificity (Levin et al., 2019).

5.1.2. Strengths

As mentioned earlier, this study is a continuation of a master's thesis that was started in 2019. Half of the data was collected by two assessors (E.V. & M.T.) from August 2019 till February 2020, and the other half of the data was collected by two new assessors (A.F. & J.N.) from July 2020 till March 2021. Hence, more participants could be recruited for this study. The first strength is the number of participants that were recruited in this master's thesis. Current literature on similar topics often only included a small amount of patients. Our larger sample size may provide a smaller margin of error and more accurate results. Further, a risk of observer bias was avoided, despite the presence of four different assessors, because all of the primary measures had an excellent inter-rater reliability. Our third strength was the extensive description of the characteristics of the included stroke population. Multiple descriptive outcome measures were used to form a clear picture of the population that was included in our study. In this way, future studies can make a better comparison with our population. All tests and questionnaires were also executed randomly so that an order bias could be avoided. Lastly, this is the first study to investigate the interrelatedness of the impairments of the shoulder, upper limb, and trunk during reaching after stroke.

5.2. Recommendations for future research

For the moment, there are no valid and reliable tests available for stroke patients that target the shoulder function, except for the Clinical Scapular Protocol. This is a domain that should be investigated by future studies. Further, the most improvement for trunk, arm and functional recovery is seen until 3 months after stroke, so a key element in the rehabilitation process is that appropriate treatments for the improvement of trunk performance and shoulder motion should be incorporated early in the process (Borschmann & Hayward, 2020; Verheyden et al., 2008). This is necessary to maximize the upper limb recovery during reaching. Because our study shows the relationship between the trunk, shoulder, upper limb and reaching performance, it is important that the deficits in the different joints are both addressed separately and together during reaching tasks. Thus, there is a need for qualitative studies investigating treatments that can contribute to improving the cooperation of the trunk, shoulder and upper limb during reaching.

6. Conclusion

The results of this study suggest that trunk, shoulder, and upper limb dysfunctions are partly related to each other and the reaching performance in people post-stroke. The upper limb and the reaching performance were consistently associated with each other, so if a stroke patient has a poor upper limb function, than the reaching performance will also be of poorer quality. Shoulder and trunk impairments may also indirectly influence the reaching performance. As they might influence the functioning of the upper limb, they can in turn affect the reaching performance. In conclusion, the key element in reaching after stroke appeared to be the upper limb functioning. Appropriate treatments for these dysfunctions should be incorporated early in the process to maximize arm function recovery and reaching.

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8. Appendix

Table 1 – Sum of scores subitems RPS-Close and RPS-Far

	0	**1**	**2**	**3**
RPS-Close				
C-TD	1	1	5	26
C-MS	1	5	12	15
C-SL	1	3	7	22
C-EM	5	2	3	23
C-PR	1	5	7	20
C-GS	1	2	12	18
RPS-Far				
F-TD	1	3	10	19
F-MS	1	7	9	16
F-SM	1	5	9	18
F-EM	2	5	5	21
F-PR	2	6	6	19
F-GS	1	4	11	17

Abbreviations: RPS-Close, Reaching Performance Scale Close Target; RPS-Far, Reaching Performance Scale Far Target; TD, Trunk Displacement; MS, Movement Smoothness; SM, Shoulder Movements; EM, Elbow Movements; PR, Prehension; GS, Global Score.

Table 2 – Mediation analyses

	a stan	**p**	**b stan**	**p**	**c' stan**	**p**	**Sobel**	**R^2**	**Adj R^2**
Model 1	0.488	0.004**	0.0242	0.228	0.154	0.441	N/A	0.118	0.059
Model 2	0.547	0.001**	0.651	0.001**	-0.085	0.627	0.009**	0.371	0.329
Model 3	0.555	0.001**	0.620	0.001**	-0.028	0.874	0.01**	0.366	0.324
Model 4	0.488	0.004**	0.403	0.034*	0.160	0.385	0.06*	0.250	0.200
Model 5	0.547	0.001**	0.727	< 0.001**	-0.042	0.790	0.004**	0.497	0.463
Model 6	0.555	0.001**	0.632	< 0.001**	0.130	0.407	0.005**	0.507	0.474
Model 7	0.488	0.004**	0.327	0.093	0.163	0.394	N/A	0.186	0.132
Model 8	0.547	0.001**	0.702	< 0.001**	-0.061	0.707	0.005**	0.299	0.277
Model 9	0.555	0.001**	0.640	< 0.001**	0.052	0.753	0.006**	0.449	0.412

Abbreviations: A stan, a standardized; b stan, b standardized; c' stan, c' standardized; R^2, R square; Adj R^2, adjusted R Square.

* $p < 0.05$; ** $p < 0.01$

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In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s):*

X behouden - *keep* ANN-SOPHIE FRANSSEN

O wijzigen - *change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

O goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

Scriptie/*Thesis:*

O openbaar (beschikbaar in de document server van de universiteit)- *public (available in document server of university)*

O vertrouwelijk (niet beschikbaar in de document server van de universiteit) - *confidential (not available in document server of university)*

Juryverdediging/*Jury Defense:*

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode/*The supervisor(s) give(s) the student(s) the non-binding advice:*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

O de verdediging is openbaar/*in public*

O de verdediging is niet openbaar/*not in public*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK C - OPTIONEEL - IN TE VULLEN DOOR STUDENT, alleen als hij luik B wil overrulen
PART C - OPTIONAL - TO BE FILLED OUT BY THE STUDENT, only if he wants to overrule part B

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode/*In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

Datum en handtekening student(en)
Date and signature student(s)

24 MEI 2021

NOBELS JUSTINE

Datum en handtekening promotor(en)
Date and signature supervisor(s)

Peter Feys

29/05/2021

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UHASSELT

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
11/09	Opstart masterproef deel 2	Promotor: [signature] Copromotor/Begeleider: [signature] Student(e): [signature] Student(e): [signature]
15/01	Stand van zaken + bespreking verder testen in covid-tijden	Promotor: Copromotor/Begeleider: [signature] Student(e): [signature] Student(e): [signature]
19/04	Stand van zaken + bespreking uitwerken resultaten	Promotor: Copromotor/Begeleider: [signature] Student(e): [signature] Student(e): [signature]
29/04	Bespreking mediator analyses	Promotor: Copromotor/Begeleider: [signature] Student(e): [signature] Student(e): [signature]
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): Ann-Sophie Franssen **Datum:** 30/05/'21

Titel Masterproef: The interaction between trunk, shoulder, and upper limb dysfunctions during reaching in a post-stroke population

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	X	O	O	O	O	O
Methodologische uitwerking	X	O	O	O	O	O
Data acquisitie	O	O	O	O	X	O
Data management	O	O	O	O	X	O
Dataverwerking/Statistiek	O	O	O	X	O	O
Rapportage	O	O	O	X	O	O

2) Niet-bindend advies: Student(e) krijgt toelating/~~geen toelating~~ (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag ~~wel~~/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
Ann-Sophie Franssen (Signature) Digitaal ondertekend door Ann-Sophie Franssen (Signature) Datum: 2021.06.06 18:58:03 +02'00'		[signature]

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): NOBELS JUSTINE **Datum:** 30 mei 2021

Titel Masterproef: THE INTERACTION BETWEEN TRUNK, SHOULDER, AND UPPER LIMB DYSFUNCTIONS DURING REACHING IN A POST-STROKE POPULATION

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	X	O	O	O	O	O
Methodologische uitwerking	X	O	O	O	O	O
Data acquisitie	O	O	X	O	O	O
Data management	O	O	O	X	O	O
Dataverwerking/Statistiek	O	O	O	X	O	O
Rapportage	O	O	O	X	O	O

2) <u>Niet-bindend advies:</u> Student(e) krijgt toelating/~~geen toelating~~ (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag ~~wel~~/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)

6 juni 2021

Datum en handtekening promotor(en)

Datum en handtekening Co-promotor(en)