Author's response to reviews

Title: Can testing of six individual muscles contribute to the diagnosis in upper limb diseases?

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Author's response to reviews: see over
Can testing of six individual muscles contribute to the diagnosis in upper limb diseases?

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Abstract

Background
It has previously been demonstrated that an extensive upper limb neurological examination of individual muscle function, sensation in homonymous innervated territories, and nerve trunk allodynia is reliable and reflects symptoms. Since this approach may appear complicated and time consuming, this studied deals with the value of an examination limited to manual testing of only six muscles.

Methods
Two examiners blinded to symptom status performed manual muscle testing of six muscles in 82 upper limbs with or without pain, weakness, and/or numbness/tingling. The six muscles represent three antagonist pairs (greater pectoral/posterior deltoid, biceps/triceps, and radial flexor of wrist/short radial extensor of wrist). The inter-rater reliability of detecting muscular weaknesses and the relation of weakness to the mentioned symptoms were analysed by kappa-statistics.

Results
The two examiners recognized weaknesses in 48 and 55 limbs, respectively, with moderate agreement (median kappa = 0.58). Out of these, 35 and 32 limbs, respectively, were symptomatic. There was good correlation between findings and symptoms for one examiner (kappa = 0.61) and fair for the other (kappa = 0.33). Both reached a high sensitivity (0.92, 0.84) but a less satisfactory specificity (0.70, 0.50). Weaknesses agreed upon by the two examiners correlated moderately with symptoms (kappa = 0.57).

Conclusions
Weakness in one or more muscles was present in almost all symptomatic limbs but also in many non-symptomatic limbs. Manual testing of six muscles may represent a useful screening approach to upper limb neuropathic conditions, but confirmative diagnostic requires further assessment.

Background
The high prevalence of work-related upper limb disorders, their effects on the quality of life and work capacity, and the limited progress concerning their diagnosis, management and prevention require new perspectives in this field of research and practice. In particular, there is a clear need of consensus regarding physical tests and diagnostic criteria of sufficient diagnostic efficacy [1,2].

It has been estimated that a standard physical approach permits diagnostic classification of only a quarter of patients with work-related upper limb disorders [3]. The remaining patients are frequently regarded as suffering from so-called “non-specific” conditions that may be labelled, e.g., “repetition strain syndrome” indicating a state of turbid pathology, which is assumed to be related to adverse physical work exposures. Even in the absence of supporting evidence in terms of physical findings, however, there is also a tendency to diagnose many upper limb patients according to the dominant location of symptoms, e.g., as epicondylitis with elbow pain or rotator cuff disorder with shoulder pain. Such diagnostics, however, do neither reflect the
type of the injured tissue, its location nor the implicated pathology. If symptoms are perceived as of a neuropathic nature, these patients are likely to be subjected to electrophysiological or imaging studies that are often of little help. Physical upper limb examinations of the peripheral nerve-functions are less emphasized.

The value of case definitions lies in their practical utility in distinguishing groups of people with the same symptoms and/or physical characteristics, or whose illness share the same causes or determinants of outcome. Therefore the best diagnostic case definition for a disorder may vary according to the purpose, e.g. epidemiological or clinical, for which it is being applied [4]. Still, the case definition should reflect the injured tissue.

Many upper limb patients present a triad of symptoms consisting of weakness, numbness/tingling and pain, which is frequently of a neuropathic character. These symptoms suggest a peripheral nerve-involvement. Patterns of neurological abnormalities defined from the course and innervation of nerves (selective muscle weakness [5], sensory abnormalities and mechanical nerve trunk allodynia) may reflect upper limb focal neuropathy with specific locations.

We have therefore developed and validated a rather extensive systematic and detailed neurological upper limb assessment with the aim to complement the standard physical examination of patients referred to a department of occupational medicine. The examination is based on the likeliness of suffering motor and sensory functions distal to an entrapped segment of a supplying nerve, and that the nerve will be abnormally sore on palpation at the location of entrapment. We have demonstrated that this examination is reliable and able to discover the presence of neurological patterns in symptomatic upper limbs and their absence in non-symptomatic limbs [6-8]. Consequently, this neurological assessment may be significant, in particular when the standard physical examination fails to identify abnormalities. This was the case in 13 out of 16 symptomatic limbs that could otherwise not be characterized diagnostically, i.e. “non-specific arm pain” [8].

Clinicians who are less familiar with the biomechanical properties of the muscles and with the course of upper limb nerves and their muscular and cutaneous innervation may regard such an extensive neurological examination [6,7] as time consuming, and difficult to perform and interpret. Therefore, a simple screening approach to the upper limb nerves would be of significance. In the 1993 meeting in The Scandinavian Society for Surgery of the Hand, Hagert presented an examination based on manual muscle testing of six muscles that were selected out of 60 shoulder and upper limb muscles to reflect focal neuropathy with specific locations (greater pectoral/posterior deltoid, biceps/triceps, and radial flexor of wrist/short radial extensor of wrist). He concluded that an affliction of the upper limb nerve tree was unlikely with normal strength in these muscles as well as in the small abductor to the 5th digit, the small abductor of the thumb, and the ulnar extensor of the wrist [9]. A more recent publication provides a detailed description of the technique of the testing of eight muscles that are representative to the upper limb nerves and the interpretation of the outcome [5].

We have adopted the muscles selected by Hagert to be assessed and his proposed examination technique, which is based on his experiences over many years. This
study aims to clarify two questions, which are crucial for the assessment of whether a limited examination is a feasible initial physical approach to the upper limb nerves:

! Is it possible to reliably identify weakness in the six upper limb muscles suggested by Hagert (Table 1)?

! Does the presence of weakness in any of these six muscles correlate to the patients’ complaints in terms of pain, weakness, and/or numbness/tingling?

Methods

Patients
The participating patients were identical to those in the previously studied consecutive series of 41 patients, 22 males of median age 44 years (range 29-61), and 19 females of median age 39 years (range 25-52). The patients were referred with any disorder (whether or not confined to the upper limbs) to the Department of Occupational Medicine, Hospital of South-western Jutland Esbjerg, preferentially for assessment of the potential work-relatedness of their disorder and the consequences for their future working life. In 22 patients complaints from one and in five patients from both upper limbs were the reason for referral. Six and three patients, respectively, were referred for reasons unrelated to present or prior upper limb complaints. Five patients have had no previous upper limb complaints [6-8].

The study complied with the Helsinki declaration. It was approved by the local Ethics Committee and signed informed consent was obtained from all participants.

Methods

Inter-rater reliability. All patients underwent identical neurological bedside assessments by two examiners. No communication occurred between the two examiners. The examinations took place in separate examination rooms and were performed in immediate succession one after the other. Both examiners were completely blinded to any patient characteristics, and the communication to the patients was limited to instructions with regard to the examination. While the examination comprised the items previously reported (14 individual muscles, as well as sensibility and mechanical nerve trunk allodynia at defined locations [6,7], the current study only assessed the outcome of the manual testing of six individual upper limb muscles (on both sides) representing three pairs of antagonists (Table 1). These muscles were selected because they are simple to remember and examine. In addition, they are reasonably representative of four (C5, C6, C7 and C8) out of the five cervical roots forming the brachial plexus (Figure 1) as well as of the brachial plexus and most individual upper limb nerves. Consequently, one or more of these muscles are likely to be involved with many upper limb nerve afflictions.

The procedure for the manual semi-quantitative isometric muscle testing and the interpretation of the test results have been described previously [5,6,10]. Weaknesses were recorded with a score of 4+ or less [11]. Each antagonist pair of muscles was examined strictly systematic from the two proximal muscles to the two distal muscles on the right and left side simultaneously with the limb positioned to optimize the isolated function of the particular muscles examined (Table 1)[6,10].
Both examiners classified each limb with respect to either the presence of weaknesses in any of the six muscles in Table 1 or to intact strength in all six muscles.

Construct validity. The construct validity of the examination can be studied by examining whether measures of constructs that theoretically should or should not be related to each other are, in fact, related to each other. Muscular weakness, which is caused by a neurologic affliction such as nerve entrapment, is likely to be symptomatic (convergent validity), while symptoms are less likely in limbs without weakness (discriminant validity). Therefore the presence or absence of weakness(es) was compared to the presence or absence of upper limb complaints (pain, weakness and/or numbness/tingling).

Information on the patients’ upper limb complaints was collected by two interviewers who did not communicate with the examiners mentioned above [8].

Statistics:
The agreement between the examiners in terms of identifying individual muscle weakness(es) and pattern(s) of weakness was assessed by Cohen’s kappa-statistics. The same statistics were employed for estimating the relation of presence of any pattern(s) to the standard criterion (pain, weakness and/or numbness/tingling).

Cohen's 6-statistics is a measure for testing whether agreement between raters of categorical data exceeds chance levels: \( \kappa = (p_0 - p_e) / (1 - p_e) \) where \( p_0 \) is the proportion of observed agreement; and \( p_e \) is the proportion of agreement expected by chance. The 6-coefficient has a maximum of 1.0 and is interpreted as kappa: < 0.2 = poor, 0.21-0.40 = fair, 0.41-0.60 = moderate, 0.61-0.80 = good, 0.81-1.00 = very good [12].

In addition, we calculated the sensitivity and specificity of the approach in terms of classifying limbs as with and without weakness, respectively, and comparing with the presence of symptoms.

Results

Inter-rater reliability
Manual testing of each of the six selected individual muscles was highly reliable. The median relative agreement and median kappa-value for the six individual muscles was 82% (range 77-87%) and 0.58 (range 0.46-0.72), respectively (Table 1).

The two examiners identified weakness in one or more muscles in 48 and 54 limbs, respectively, with agreement on the presence or absence of any weakness in 43 and 23 limbs, respectively, and disagreement in 16 limbs (Table 2). The resulting inter-rater reliability was moderate (80% relative agreement, \( \kappa = 0.59 \)).

Correlation between the presence of symptoms and the identification of weakness by the two examiners
For one examiner, the examination of the six muscles resulted in a good correlation between the identification of any weakness and the presence of symptoms (\( \kappa = 0.61 \)) while the other achieved a fair correlation only (\( \kappa = 0.33 \)). The two examiners found weakness in one or more muscles in 35 and 32, respectively, out of
38 symptomatic limbs. No weakness was found in 31 and 22, respectively, out of 44 non-symptomatic limbs.

Consequently, the diagnostic sensitivity of the assessment by each examiner was 0.92 and 0.84, respectively, and the specificity 0.70 and 0.50, respectively. In this sample, the positive/negative predictive values with respect to symptoms were 0.73/0.91, respectively, for one examiner and 0.59/0.79 for the other (Table 3).

**Correlation to symptoms with agreement between the two examiners**

In 79% of limbs with unanimous rating of presence or absence of weakness by the two examiners, the rating was in agreement with the presence of symptoms and the kappa-value was thus calculated to 0.57. The sensitivity of unanimously concluding the presence of weakness in symptomatic limbs was 0.84 while the specificity of identifying absence of weakness in non-symptomatic limbs was just 0.45. The positive and negative predictive values were 0.74 and 0.87, respectively (Table 4).

**Discussion**

The neurological examination, in particular the assessment of individual muscle function, is disfavoured by being assumed by many as “subjective” and consequently not trustworthy. In spite of little evidence for such a standpoint, many and frequently severely affected patients that complain of upper limb pain, numbness and/or weakness are met with scepticism and a tendency to reject a somatic origin of their symptoms [13-16]. This, in particular, may apply for the many patients with work-related upper limb complaints that are unclassifiable according to current examination practices and diagnostic criteria.

The previously presented extensive examination of neurological items selected to represent the function of the upper limb nerves has been shown to be both precise and accurate in terms of predicting symptoms [6-8](Table 4). It may, however, be regarded as complicated to perform and interpret.

There were several reasons for studying the feasibility of limiting an upper limb neurological examination to the assessment of strength in only six upper limb muscles. I was concerned about the obvious diagnostic difficulties that clinicians face with upper limb patients – in particular patients that cannot be classified according to common diagnostic criteria, and also about the unjustified but widespread use of diagnostic labelling based on physical findings that neither reflects the injured tissue nor its location and pathology. However, I was also concerned about arguing for an extensive neurological examination that clinicians may find too difficult or time consuming. To meet this challenge the aim was to present a simple examination of neurological items, which by the identification of neurological signs can complement the standard physical upper limb examination and with a high degree of certainty can explain symptoms that could be due to a nerve-related condition.

Manual testing of only three pairs of antagonist muscles working over the shoulder, the elbow and the wrist is rapid and easy to remember. The interpretation of the outcome of this examination is also relatively simple. Muscle weakness was frequent in the studied sample of patients and could be reliably identified (median kappa-value 0.58, Table 1). This reliability is acceptable and in fact superior to that of other parts of the neurological examination, which one usually trusts, e.g. the Babinski sign [17].
The consistency of findings between the two examiners argues against a bias within the examiners or the way of examining the patients. Therefore the testing of these six muscles meets the requirements of simplicity and reliability.

The two examiners found weakness in one or more muscles in 92% and 84% of the 38 symptomatic limbs, respectively, meaning that this limited examination is able to identify weakness in almost all symptomatic limbs in the studied sample. With full inter-rater agreement, the estimates of the two examiners with regard to the presence or absence of weakness reflected moderately well the subjective symptoms (kappa = 0.57). With agreement between the two examiners, the sensitivity of this limited examination was even higher than that of the previously presented extensive examination (0.84 and 0.73, respectively) [8]. The implication of this finding is that in the studied sample of patients, a nerve involvement is unlikely with intact strength in all six muscles.

The two examiners also identified weaknesses in a high proportion (30% and 50%, respectively) of the 44 non-symptomatic limbs (Table 4). With agreement between the two examiners, the specificity of the examination limited to six muscles was only 0.45 (Table 5) while the previously presented extensive examination was much more specific (0.86) [8]. This low specificity indicates that an examination limited to the testing of six muscles is clearly not suitable for confirmative diagnostic purposes and that the identification of reduced strength requires further examination to identify or rule out a nerve affliction.

The concept of weakness
Weakness can be an objective and/or a subjective phenomenon. It may be of a global character or limited to one or a few muscles, e.g. muscles with shared innervation.

Weakness may reflect muscles of a healthy subject in a bad physical condition, e.g. consequent to inactivity, or be related to asthenia accompanying a disorder that may or may not be confined to the musculoskeletal system per se. Muscular weakness may also be simulated for the achievement of some advantage. Common to these situations is that weaknesses rarely occur in patterns with some muscles weak and other intact. Weakness may also be pain-induced (although this term is probably used more than justified). Pain-induced weakness tends to involve a single muscle while other muscles with the same innervation can usually be tested without pain-aggravation.

Whether or not muscular weakness is experienced by the patient, the objective phenomenon of identifying reduced strength in one or more individual muscles during the physical examination may be subject to interpretation. Individual or patterns of weakness are not necessary due to pareses and consequently to an affliction of the peripheral (or central) nervous system. Global weakness (in all six examined muscles) is rare but if present may represent an affliction of all cords of the brachial plexus as well as the causes listed above. Weakness in a single muscle may also have other causes than an affliction of the innervation of that muscle. Weaknesses in several muscles with a pattern in accordance with the innervation are more likely to represent pareses.

A pattern of muscular paresis, which occur secondary to a peripheral nerve affliction such as entrapment is more likely to be accompanied with mechanical nerve trunk
allodynia at the site of entrapment [7]. The absence of nerve trunk soreness, on the other hand, argues against ongoing nerve entrapment as causing the weakness. In the same way, muscular weakness accompanied by impaired sensation is more likely to represent a paresis if the muscular and cutaneous innervation is shared. Consequently, the demonstration of nerve trunk allodynia or sensory dysfunction with an appropriate location will increase the specificity of the examination of muscle strength.

In the previous study of the same sample of patients, there was remarkable tenderness of nerve trunks with specific locations that were related to the discovered patterns of weakness [7]. This finding suggests that the identified weaknesses represent pareses. E.g. mechanical allodynia was present at the brachial plexus in the deltoid-pectoral groove in all 14 limbs in which both examiners identified a pattern of weakness (posterior deltoid, biceps, flexor carpi of the wrist) in accordance with an infraclavicular brachial plexopathy (pectoralis minor syndrome) [7]. Therefore, the assessment of nerve trunk allodynia in addition to muscle strength testing would improve specificity.

**Standard for comparison**

Pareses would most likely be symptomatic (convergent validity), while symptoms would be less probable in limbs without pareses (discriminant validity). This logic applies despite the recognition that symptoms may have other causes than nerve affliction(s), and that nerve afflictions may be non-symptomatic. While it is therefore acknowledged that symptoms are not an ideal standard for comparison, it is, however, not possible to apply a better standard in this study. A golden standard does not exist [8].

For electrophysiology to serve as golden standard would require a global assessment of nerve conduction at many levels in a large number of nerves as well as electromyographic studies of multiple muscles. Such an extensive bilateral examination of the upper limb nerves, the brachial plexus and the roots would be painful, expensive and very time consuming, and just for that reason not feasible. More importantly, however, electrophysiology is subject to interpretation and for technical and other reasons cannot serve as a valid estimate for focal neuropathy [18]. E.g. median nerve compression at the elbow level (pronator syndrome) can rarely be detected by the measurement of motor or sensory conduction velocity [19,20]. The electrophysiological diagnosis of radial tunnel syndrome is also unreliable [21]. Brachial plexopathy constitutes a major challenge with regard to electrodiagnosis [22-25]. Unfounded confidence to the electrophysiological assessment of nerve entrapments such as these may prevent a correct diagnosis by failing to emphasize physical neurological parameters such as those applied in this and previous studies [6,7]. Similar limitations apply for imaging studies.

**Interpretation**

Muscle weakness in accordance with the innervation suggests to the examiner that the patient is trustworthy while occurrence with a random distribution should be scrutinized critically. Interpretation of the outcome of muscle testing has been provided by Hagert and Hagert [5]. With a normal strength in the six muscles selected for this study, several locations of neuropathy would be unlikely, e.g. the brachial plexus, the axillary nerve, the radial nerve, and the median nerve at elbow level. On the other hand, unless weakness in any of these muscles cannot be satisfactorily
explained from other reasoning in a symptomatic limb, the clinician should not uncritically conclude neuropathy to be absent.

The identification of any weak muscle should be followed by a more comprehensive examination of the upper limb nerves in order to provide further evidence in defining and locating a nerve affliction of some kind, e.g. testing of additional muscles and assessment of further neurological items, in particular mechanical nerve trunk allodynia [6-8]. With weakness in any of the six muscles, the isolated presence of carpal tunnel syndrome, ulnar neuropathy, and radial tunnel syndrome is unlikely. One should recognize the potential presence of double or multiple crush [26,27], both of which are according to our previous studies very common in the studied sample of upper limb patients [7].

Limitations
The studied six muscles do neither represent the Th1 root nor three common upper limb nerve entrapments: ulnar neuropathy at the level of the elbow as well as the wrist, carpal tunnel syndrome and radial tunnel syndrome. The identification of ulnar neuropathy, carpal tunnel syndrome and radial tunnel syndrome requires testing of the strength in the abductor digiti minimi, the abductor pollicis brevis, and the extensor carpi ulnaris muscles, respectively [10]. These conditions may occur in isolation or accompany a more proximal affliction of the radial or median nerves, the brachial plexus, or the roots. The high sensitivity in the examined sample indicates the adequacy of testing six muscles only and the rarity of the isolated presence of these three common locations of entrapment.

Symptoms are not necessarily caused by afflictions of the peripheral nerves but may also be caused by upper limb disorders of a non-neurogenous character that should consequently also be examined for. These disorders may occur in isolation or complicate, cause, or accompany upper limb neuropathy. E.g. brachial plexopathy may complicate a shoulder tendonitis; lateral epicondylitis or radio-humeral joint inflammation may affect the adjacent radial or posterior interosseous nerves; carpal tunnel syndrome may develop secondary to increased pressure from inflamed flexor tendons in the carpal tunnel.

Neuropathic symptoms may be located distant to a focal lesion, e.g. elbow or wrist pain may originate from brachial plexopathy or from cervical root compression. Therefore the physical upper limb examination should not to be limited to the symptomatic area but cover the neck and the whole limb.

Clinicians tend to initially interpret upper limb neuropathic pain and dysfunction as carpal tunnel syndrome or cervical root compression while the involvement of the almost one metre long intermediate portion of the upper limb nerve-tree may is less contemplated and less examined for. Taking into account the frequency among patients in occupational medicine of findings in accordance with infraclavicular brachial plexopathy, and median and posterior interosseous neuropathy at elbow level [7] the authors consider this as a major problem.

Consequences of the findings
The low specificity (0.45) of an examination limited to six muscles is clearly insufficient for confirmative diagnostics while the high sensitivity may suggest that it
may be applied as a screening tool for upper limb neuropathy, which can be used in the clinical setting as well as for surveillance of in populations, e.g. of workers, in risk of upper limb neuropathy. The feasibility for use in screening should be studied in exposed populations with varying disease frequency and severity. We have demonstrated that the outcome of a more extensive blinded examination of neurological items in a sample of “healthy” and active computer operators was related to symptom status [28].

**Upper limb neuropathy as a work-related condition – relation to repetition strain syndrome**

This study has not aimed to analyze causation but merely to assess the potentials of a simple physical assessment of the muscle function in a sample of patients referred to a hospital clinic of occupational medicine. However, a number of reports have dealt with work-related nerve afflictions [27,29] including brachial plexopathy [22,30]. Werner [31] and Hagert et al. [32] reported rotational loads of the forearm causing radial tunnel syndrome rather than epikondylitis, and Stål et al. described pronator syndrome in a high proportion of female milkers [33]. Recent epidemiological evidence support the work-relatedness of, e.g. radial tunnel syndrome [34].

In the current material, however, isolated radial tunnel syndrome was not looked for, nor was any case of isolated pronator syndrome identified. However, the frequency of muscle weaknesses in this study represents neurological patterns that have previously been identified in the same sample of patients referred to an occupational health clinic. These patterns suggest that the infraclavicular brachial plexus is frequently involved [7] – a finding which is supported by the clinical experiences of others [27,35].

**Conclusions**

Manual testing of six upper limb muscles is simple to learn and interpret, and rapid to perform. We have shown that this examination is also reliable and that the outcome of the examination reflects the symptoms.

In the studied sample of patients referred to a department of occupational medicine this examination has proved to be highly sensitive in identifying weakness that may be related to nerve afflictions. Due to limited specificity, however, this examination is not suitable for diagnostic confirmation but may rather serve as a preliminary screening approach for upper limb neuropathy in individual patients as well as in populations. This examination may be particularly useful when the conventional physical upper limb examination cannot, or cannot fully, explain complaints.

If positive, this examination should be followed by further neurological assessment. If negative, the examiner should still consider the presence of neuropathic conditions that are not covered by this examination, in particular ulnar neuropathy, radial tunnel syndrome, and carpal tunnel syndrome.

Our study does not support the general assumption that altered muscle function cannot be detected in patients with mild nerve compression [29]. In fact, it rather suggests that the failure of including individual muscle strength testing in the physical examination of upper limb patients – in particular those which would otherwise be
diagnostically non-classifiable may have unintended consequences. In the clinical setting, patients may be misinterpreted and mismanaged, or not managed at all. In epidemiological studies, insensitive measures of health effects may result in erroneous negative results and consequently missed prevention.

The presented findings may argue that clinicians dealing with upper limb disorders should include manual assessment of muscle strength in six muscles in the physical examination. The identified patterns of pareses are frequent in many “non-specific” upper limb disorders such as repetition strain injury and likely to reflect afflictions of the upper limb peripheral nerves.

**Competing interests**
The author declares that there are no competing interests.

**Acknowledgements**
C-G Hagert has developed the physical diagnostic approach concerning the systematic testing of individual muscles and the identification of soreness at potential locations of neuropathy. Financial support has been received from Statens Sundhedsvidsenskabelige Forskningsråd, Copenhagen (Grant nr. 9702593), Den Samfundsvidenskabelige Forskningsfond, Ringkøbing (Grant nr. 2-44-4-18-97), and Lida & Oskar Nielsens Fond, Esbjerg.

**Figures**

**Figure 1 - Roots, brachial plexus, and upper limb peripheral nerves**
Overview and innervation of the selected six upper limb muscles

**Figure 2 - Standard posture I. Testing of the pectoral muscle**
The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The posterior deltoid muscle works as the antagonist.

**Figure 3 - Standard posture I. Testing of the posterior deltoid muscle**
The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The pectoral muscle works as the antagonist.

**Figure 4 - Standard posture II. Testing of the biceps brachii muscle**
The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The triceps muscle works as the antagonist.

**Figure 5 - Standard posture II. Testing of the triceps muscle**
The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The biceps brachii muscle works as the antagonist.

**Figure 6 - Standard posture III. Testing of the flexor carpi radialis muscle**
The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The short extensor of wrist muscle works as the antagonist.
Figure 7 - Standard posture III. Testing of the extensor carpi radialis brevis muscle

The arrow illustrates the direction of the examiner’s force against the patient’s resistance. The flexor carpi radialis muscle works as the antagonist.

Tables

Table 1 - Manual testing of three muscle antagonist pairs in 82 upper limbs

Table 2 - Inter-rater reliability of the definition of neuropathy by the two examiners based on muscle testing

Table 3 - Upper limb symptoms related to the identification of patterns of weakness in six muscles

Table 4 - Agreement between the patterns identified by the two examiners and the relation to symptom status
## Table 1 - Manual testing of three muscle antagonist pairs in 82 upper limbs

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Greater pectorals</td>
<td>Pectorals</td>
<td></td>
<td></td>
<td>16</td>
<td>21</td>
<td>84</td>
<td>0.55</td>
<td>90° flexion in shoulders. Upper extremities placed horizontally forward, forearms pronated (Figures 2 – 3)</td>
</tr>
<tr>
<td>Posterior deltoid</td>
<td>Axillary</td>
<td></td>
<td></td>
<td>48</td>
<td>50</td>
<td>80</td>
<td>0.59</td>
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<tr>
<td>Biceps brachii</td>
<td>Musculocutaneous</td>
<td></td>
<td></td>
<td>36</td>
<td>31</td>
<td>79</td>
<td>0.57</td>
<td>90° flexion in elbows. Upper arms placed vertically against the lateral chest and forearms horizontally. The supinator function of the biceps may additionally be tested (Figures 4 – 5)</td>
</tr>
<tr>
<td>Triceps</td>
<td>Radial</td>
<td></td>
<td></td>
<td>34</td>
<td>33</td>
<td>87</td>
<td>0.72</td>
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<tr>
<td>Radial flexor of wrist</td>
<td>Median</td>
<td></td>
<td></td>
<td>32</td>
<td>32</td>
<td>77</td>
<td>0.46</td>
<td>90° flexion in elbows. Forearms resting fully on tights: For the testing of the radial flexor of wrist, forearms are supinated and fingers flexed. For the testing of the short radial extensor of wrist, forearms are pronated and fingers extended (Figures 6 – 7)</td>
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<td>Short radial extensor of wrist</td>
<td>Radial</td>
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<td>29</td>
<td>20</td>
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Table 2 - Inter-rater reliability of the identification by the two examiners of any weakness in six muscles

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<th>Total</th>
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<tr>
<td>Absent</td>
<td>23</td>
<td>34</td>
</tr>
<tr>
<td>Present</td>
<td>5</td>
<td>48</td>
</tr>
</tbody>
</table>

| Total        | 28         | 54    | 82    |
Table 3 - Upper limb symptoms related to the identification of any weakness in six muscles

<table>
<thead>
<tr>
<th>Upper limb symptoms</th>
<th>Examiner 1</th>
<th></th>
<th></th>
<th></th>
<th>Examiner 2</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No weakness identified</td>
<td>Any weakness present</td>
<td>Kappa</td>
<td>No weakness identified</td>
<td>Any weakness present</td>
<td>Kappa</td>
<td></td>
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<tr>
<td>Absent</td>
<td>31</td>
<td>13</td>
<td>0.61</td>
<td>22</td>
<td>22</td>
<td>0.33</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>3</td>
<td>35</td>
<td>6</td>
<td>32</td>
<td>32</td>
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<td>38</td>
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</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>48</td>
<td>28</td>
<td>54</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4 - Agreement between the identification of any weakness by the two examiners and the relation to symptom status

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Agreement on absence</th>
<th>Disagreement</th>
<th>Agreement on presence</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent</td>
<td>20 (38)</td>
<td>13 (4)</td>
<td>11 (2)</td>
<td>44</td>
</tr>
<tr>
<td>Present</td>
<td>3 (4)</td>
<td>3 (6)</td>
<td>32 (28)</td>
<td>38</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>16</td>
<td>43</td>
<td>82</td>
</tr>
</tbody>
</table>

The numbers in brackets represent the corresponding figures with application of the full examination [8].
References

1. Marx RG, Bombardier C, Wright JG. What do we know about the reliability and validity of physical examination tests used to examine the upper extremity? *J Hand Surg (Am)* 1999;24:185-193.


