EFFECT OF HAND EXERCISES PROGRAM ON WRIST PROPRIOCEPTION, GRIP STRENGTH AND HAND FUNCTION IN PATIENTS WITH TYPE 2 DIABETIC POLYNEUROPATHY: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Patients with diabetic polyneuropathy (DPN) due to type 2 diabetes mellitus (DM) are commonly suffering from deficits in proprioception and hand dexterity. Intact sensory information of the wrist (tactile and proprioceptive) are prerequisites for hand function.

Objective: This study was conducted to investigate the effect of hand exercises program on wrist proprioception, grip strength and hand function in patients with type 2 DPN.

Methods: Forty male patients with type 2 DPN aging from 50 to 65 years were randomly divided into study group and control group. Study group (n=20) received hand exercises program consisting of proprioceptive training and strength training in addition to conventional physical therapy training 3 days a week for four weeks. While the control group (n = 20) received conventional physical therapy only 3 days a week for four weeks. Wrist joint position sense was assessed using Biodex isokinetic dynamometer through determining angular displacement error of active angle repositioning of wrist extension, grip strength was measured using JAMAR hand dynamometer while hand function was evaluated by Jebsen Taylor Hand Function Test (JTHFT). Measurement of all variables was done pre and post-treatment.

Result: within group analysis revealed that there were statistically significant improvement in all measured outcomes in both groups post treatment compared with pretreatment (P < 0.05). Between group analysis showed significant improvement in all measured variables in favor of intervention group (P < 0.05).

Conclusion: Hand exercises program (proprioceptive and strength training exercises) is more effective in improving wrist proprioception, grip strength and hand function of patients with type 2 DPN than that of patients received conventional physical therapy only. So, wrist proprioceptive and hand strength training are effective strategies for improving deficits in wrist proprioception and hand function in patients with DPN.

Keywords: Proprioceptive training, Strength training, Diabetic polyneuropathy, Type 2 diabetes mellitus, Hand grip strength, Biodex isokinetic dynamometer, Hand function.

I. INTRODUCTION

Diabetes mellitus (DM) is defined as chronic metabolic disease characterized by hyperglycemia with defect in carbohydrate, fat and protein metabolism. It is caused by absolute or relative deficit in insulin secretion and/or action [1]. Type 2 DM is considered the most common endocrinial disorder across the globe. According to International Diabetes Federation (IDF), the prevalence of type 2DM is about 415 million adults worldwide and is more common in low and middle socio-economic regions [2].

Type 2 DM can affect many body parts such as diabetic cardiovascular problems, nephropathy, retinopathy and peripheral neuropathy [3]. One of the most common complication of DM is diabetic peripheral neuropathy (DPN); it affects sensory and/or motor peripheral nerves, leading to decreased tactile sense, nerve conduction...
velocity, and can affect the motor function in more advanced stages of the disease [4,5]. Most of the previous studies concentrated on the DPN outcomes on the lower extremity especially the diabetic foot [6], but few studies demonstrated that the hands of the patients with DM are more commonly affected by the sensory and motor functions deficits [7–10].

Many hand complications could be seen in type 2DM such as limited joint mobility (diabetic cheiroarthropathy or stiff hand syndrome), flexor tenosynovitis (trigger finger), carpal tunnel syndrome and Dupuytren’s contracture [11]. These complications can affect the daily living activities such as self-care activities leading to decrease the quality of life [12].

Also, several studies demonstrated a significant decrease in muscle strength in patients with type 2 DM in comparison with age matched healthy subjects [13-15]. It was attributed to two mechanisms: 1) Increase in both insulin resistance and blood sugar which lead to decrease in the mitochondria number in the muscle cells, diminished synthesis of glycogen and increased amount of circulating systemic inflammatory cytokines, all of these changes have a negative impact on skeletal muscles, 2) The neurological process which affects the motor neurons in more advanced stages of the disease [16, 17].

Diabetic peripheral neuropathy can affect the hands sensory function which may result in negative consequences on hand dexterity, maximum grip strength and grip force control during object manipulation [18]. Hand grip strength (HGS) defined as the maximal power produced by a forceful voluntary flexion of all fingers under the normal bio kinetic conditions[19]. Previous studies demonstrated a significant reduction in grip strength in DPN patients [18,20,21], these individuals exert higher magnitudes of grip force while catching and transferring an object to prevent it from slippage [18,22].

Proprioception, also referred to as kinaesthesia (or kinesthesia), is sense of self-movement and body position [23]. It is sometimes called the sixth sense [24] and is carried by proprioceptors; the mechanosensory neurons which are located within muscles, tendons, and joints [23]. It gives us important information about position of ourbody parts in relation to each other and to the environment [25]. The muscle spindles have an important role in the proprioception sense through the joint range of motion [26].

Diabetic patients may have proprioceptive impairment due to development of peripheral Neuropathy [27]. Deficits in proprioceptive sense in the upper extremities with sensory deafferentation studied in many previous researches [28, 29]. In the patients with diabetic sensory neuropathy, the accuracy and precision of the thumb during performance of flexion movement at the interphalangeal joint are severely affected [29].

Proprioceptive training is an intervention which aims to improve the function of proprioception. It concentrates on utilizing somatosensory signals like a proprioceptive or tactile afferents in absence of vision. The final aim of proprioceptive training is sensorimotor function improvement or restoration [30].

Also, exercises lead to improvement of the glycemic control which may reduce or stop the progression of the DPN e.g. resistance training improves muscle strength and increases the endurance and lead to improvement in the glucose tolerance and insulin sensitivity [21, 29]. Grip muscles strength training is shown to improve the strength and endurance of the grip muscles and thus improve the hand function in the patients with DPN [31].

Few previous studies mentioned the effect of hand exercises on HGS in patients with DPN [31, 32], but these studies didn’t clarify the effect of hand exercise (proprioceptive and strength training) on wrist proprioception and hand function in these patients, so the propose of the current study is to identify the effect of hand exercises program on wrist proprioception, grip strength and hand function in the patients with type 2 DPN.

II. MATERIALS AND METHODS

This randomized controlled clinical trial was carried out at Faculty of physical therapy, Cairo University in the period from October 2020 to March 2021. The details of study protocol was demonstrated for each patient before the participation in the study to ensure complete satisfaction and all patients signed an institutionally approved informed consent which was approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (PT REC/012/002573).
2.1. Study population

54 right-handed male patients with type 2 DPN were initially screened. Type 2 DPN was diagnosed based on careful history taking and neurological examination conducted by a neurologist and confirmed by electrodiagnostic tests. These patients were recruited for this study from the outpatient Clinics of Neurology and Internal Medicine in Kasr Al-Aini Hospitals and outpatient Clinic of Department of Neurology, Faculty of Physical Therapy, Cairo University. After the screening process, 40 patients were eligible to participate in this study if they had the following criteria (i) age ranged from 50 to 65 years old [18]; (ii) a diagnosis of the type 2DM for at least 10 years [18]; (iii) body mass index did not exceed 30 Kg/m2; (iv) controlled blood glucose level by the examination via Glycated Haemoglobin exam (9 % > HbA1c > 6.5 %)[33]; (v) score ranged from 6 to 8 (moderate severity) according to neuropathy disability score[34]; (vi) ability to understand and follow simple instructions. While, patients were excluded if they exhibited one of the following criteria(i) other neurological or orthopaedic impairments affecting the hands (such as stroke, ataxia, poliomyelitis, rheumatoid arthritis, or severe osteoarthritis and joint stiffness); (ii) patients with history of cervical spondylosis, carpal tunnel syndrome, peripheral nerve injury and cervical radiculopathy during the previous 6 months; (iii) patients with pain and musculoskeletal problems in the shoulder, arm;(iv) patients involved in an occupation that required manual handling that can influence the handgrip.

2.2. Randomization

54 patients assessed for eligibility after the screening process, ten patients were excluded as they did not fulfill the inclusion criteria and four patients were excluded as they refused to participate in the study. A randomization process was performed for 40 patients by an author who picked one of the sealed envelopes, which contained numbers chosen by random number generator. Randomization was restricted to permuted blocks of different size to ensure that equal numbers were allocated to each group. Each random permuted block was transferred to a sequence of consecutively numbered, sealed, opaque envelopes and these were stored in a locked drawer until required. As each patient formally entered the trial, the researcher opened the next envelope in the sequence in the presence of the patient.

A diagram of patient's retention and randomization during the study is shown in Fig. 1.

Patients were randomly assigned to two groups: 1) study group who received hand exercises program in addition to conventional physical therapy which included 20 patients and control group who received conventional physical therapy which included 20 patients. During study period, both study and control groups continued to receive the usual recommended medical care.
Figure 1: Flow chart of study participants

2.3. Outcome measures:
Measurement of the variables was performed by the same outcome assessor for each patient individually before and after 4 weeks of treatment to prevent interrater variability. The outcome assessor was blinded to the treatment groups. All outcome measures were performed on the right upper extremity.

The primary outcome measure is wrist joint position sense (JPS) using Biodex System III Multi-Joint testing and Rehabilitation System (Biodex Medical Inc., Shirley, NY) through determining angular displacement error of active angle repositioning of wrist extension in patients with DPN. Assessment of wrist JPS in both groups was performed only on the right wrist. The Biodex Systems Three consists of a dynamometer, positioning chair, a computer and different types of attachments for testing of different body parts (Biodex system 3 pro manual).

Before collecting data, isokinetic dynamometers was calibrated according to the manufacturer’s instructions. The patient’s name-surname, gender, birthdate, height, weight, and dominant side were entered into the system prior to assessment start. The following adjustments were done: the seat orientation was 0 degrees, seat back tilt was 85 degrees, dynamometer orientation was 0 degrees, dynamometer tilting was 0 degrees and angular velocity was two degrees per second [35]. The patient was adjusted in sitting with proper fixation and stabilization of the trunk. The patient's right elbow was positioned in 90°, and the right forearm was pronated and stabilized with a strap. Dynamometer’s rotation axis lies between the proximal row of the carpals, at the capitate bone, and the radius at the radiocarpal joint.

To avoid visual input, all patients were blindfolded during the examination. The selected target angle was 30° wrist extension which is functional position of the wrist [36]. In order to establish familiarization, dynamometer range was limited between 30° extension and 0°; Each patient was instructed to move the right wrist to a target angle 30° wrist extension relative to starting position (0°) and the dynamometer stopped the movement when the target angle was reached. Patient was instructed to wait 5 seconds at the target position to sense it as a method for educating the patient, so the patient could remember that position [37] and then the wrist returned passively to the starting position. Then the patient was asked to actively move his wrist to the target angle (30°). When the
patient felt that the target angle was reached, he would press the Hold/Release button to stop the apparatus with his non tested hand. The protocol composed of three trials with 10 seconds interval period between trials [38]. The mean of the angular differences of the three trials, between the target angle position (30°) wrist extension and the reached end range position by the patient was calculated in degrees and recorded as the absolute error (angular displacement error). This error was used in the statistical analysis. The measurements were performed pre and post treatment.

The secondary outcome measures included HGS and hand function:

1) Hand grip strength was evaluated by JAMAR hydraulic hand dynamometer. This hand-held dynamometer is a reliable, objective way to obtain measurements of grip strength in elderly and subjects with physical impairment. It is a portable device that can be used to obtain more discrete, objective measures of strength than traditional manual muscle testing [39].

The patient was instructed to sit in a straight back chair without an arm rest with their feet flat on floor. Each patient was asked to place his right upper limb in the following position; shoulder adduction and internal rotation, with approximately 90° elbow flexion, the forearm and wrist were in neutral position, and the fingers were flexed for the required maximum contraction. Each patient was instructed to breathe in through the nose and exhale through a pursed lip after a maximum grip effort was made. A demonstration of maximum HGS was given to each patient before they were asked to do it themselves. Each patient was instructed to squeeze the handle of the dynamometer which was placed vertically in their right hands as hard as possible before and during the measurements. The period of the effort did not exceed 5 seconds. Three trials were made with a pause of about 30 seconds between each trial to avoid the effect of fatigue. The dynamometer was reset to zero prior to each reading according to [21,40]. The three trials mean value was calculated. The measurements were performed pre and post treatment.

2) Hand function assessment

Hand function was evaluated via Jebsen Taylor Hand Function test (JTHFT). It is a standardized and objective measure for both fine and gross motor hand function by simulated activities of daily living. This test composed of seven subtests: (a) writing (copying) a 24-letter sentence; (b) card turning over (simulated page turning); (c) picking up small common objects (e.g. pennies, paper clips, bottle caps and coin) and placing objects in a container; (d) stacking checkers (test of eye-hand co-ordination); (e) simulated feeding using a teaspoon and five kidney beans;(f) lifting large light objects (empty cans;) and (g) lifting large heavy objects (full can)[41]. Jebsen Taylor Hand Function test is an easy applicable tool in clinics because materials used for the test are readily available and the test takes a short time to be completed [42] Jebsen Taylor Hand Function test is a valid tool for assessment of hand dysfunction and has been commonly used in the clinical and research settings and also in various patients[43,44].

During the test, the patients were asked to do these tasks as rapidly and accurately as possible with his right hand and the number of seconds needed to complete each subtest was recorded via a stopwatch, then the total time was calculated. Lower scores indicated greater hand function levels. Measurement was performed pre and post treatment.

2.4. Intervention

The same physiotherapist was responsible for all training sessions. Control group received conventional physical therapy program for 3 days per week for four weeks. Each session lasted for 30 minutes. Conventional physical therapy program include the following exercises:

1. Active range of motion exercises for wrist joint including wrist flexion, wrist extension, ulnar deviation and radial deviation.
2. Stretching exercises for flexors of the wrist: The exercises were done according to the patient’s tolerance for thirty seconds and rest for thirty seconds.
3. Strength exercises
   - Graduated active resistive exercises
   - Isometric hooks exercises
• Pinching clothespin with each finger: Patient was instructed to take clothespin and practice pinching it with different fingers.

4. Exercises to facilitate the function of hand including reaching, grasping, carrying, release different objects. The patient was instructed to sit and perform these exercises after demonstrating it. These exercises were in form of the following as described by Thabet et al.[45]:

• Grasping a cube: Each patient was instructed to grasp cubes placed in box within his hand reach.

• Transferring cube: Each patient was instructed to pick up cubes then put cubes in the physical therapist's hand.

• Releasing cube: Each patient was instructed to release or drop the cubes placed in his hand into a container placed in front of him.

• Stacking coins: Each patient was asked to stacking coins on top of each other.

• Turning pages: Each patient was asked to open a thick large book placed on a table and turn pages.

• Writing activities:

Study group received hand exercises program including proprioceptive training and hand strength training 3 times per week for four weeks, 30 min per session in addition to the conventional physical therapy program received in the control group. Rest periods were given as needed and each patient was instructed to tell the physiotherapist and stop the exercise immediately if they experience any side effects such as fatigue or dizziness. The proprioceptive practice exercises performed in the current study was applied after modifying and completing the exercises done by[45-47]. Proprioceptive training exercises used in this study are a mixture of open and closed kinetic chain exercises which include following groups of exercises.

a) Proprioceptive exercise

1. Isometric exercise: Patient was instructed to sit with forearm pronated and hand resting flat on the table placed in front of him then the physical therapist apply manual resistance on hand dorsal-radial side (for extensor carpi radialis) while forearm supinated and hand resting on the table and manual resistance applied on palm (for flexor carpi ulnaris and flexor carpi radialis) (each movement repeated 10 times, and hold for 5 seconds).

2. Rhythmic stabilization: The patient was instructed to position his wrist in different angles of wrist flexion/extension and hold this isometric contraction. Then manual perturbation applied by the therapist (3 s for 10 times ) for coactivation of agonists and antagonists. The physical therapist provides enough resistance to cause the patient to react, but not enough to break the isometric contraction [48]. As the patient progresses, length of time of rhythmic stabilization increases, and therapist resistance increases.

3. Duplicating position: Patient's wrist was moved passively to a position within its available range of motion, then returned it to its resting position. Again, therapist emphasize the affected positions. Then, the patient was instructed to actively repeat the movement, first with his eyes open, then closed. If the patient misses the position, he opens his eyes and actively moves to the desired position. Perform 10 to 20 repetitions of varying positions and held that position for three seconds.

4. Dart-throwing motion with weight placed in hand: The patient was instructed to start with 1 lb dumbbell and progress according to his tolerance. 2 sets of 10 repetitions

5. Throwing into rebounder. The patient was instructed to throw and catch medicine ball with forearm in pronation, 2 sets of 10 repetition. Patient starts with 1 lb medicine ball and progress according to his tolerance.

6. A controlled weight-bearing exercise. The patient was standing facing the wall. Then patient was instructed to press a soft ball against the wall. The same exercise can be performed while the patient was standing in front of table and press on a soft ball placed on the table.

7. The Wobble Board Balance exercise: The patient was instructed to assume the quadruped position on the floor with their upper body positioned over a wobble board. Elbow joint should be kept straight and shoulder joint should be flexed to approximately 90. Patient’s upper body weight was positioned over the upper limbs. The patients rocked their wrist in the following directions; flexion, extension, and radial and ulnar deviation for 30 seconds while maintaining their balance. This exercise was performed first with eyes open, then closed. Perform 5 to 10 repetitions.
b) Strength training as described by Thorat and Ganvir [32]:

1) Squeeze ball exercise: Each patient was instructed to sit and squeeze ball and wait for 10 seconds count.

2) Spring Hand Dynamometer: Each patient was instructed to sit and spring and press hand dynamometer placed in his hand and wait for 10 seconds.

3) Rubber band exercise: i] Each patient was instructed to sit with shoulder in neutral position and both elbow and finger (metacarpophalangeal joint) were flexed. Rubber band was wrapped around the patient's fingers and patient was asked to perform fingers extension.

ii] The patient was asked to sit with shoulder in neutral position, elbow flexed and forearm pronated then rubber band was wrapped around his fingers and the patient was asked to do abduction of the fingers.

2.5. Sample size:

The G*power 3.0.10 software was used to calculate the sample size. Calculation of the numbers of patients in this study depending on a pilot study from 10 patients with type 2 DPN. The patients were assigned randomly to two groups; one group received hand exercises program in addition to conventional physical therapy and the other group received conventional physical therapy only. The primary dependent measure was wrist JPS and its effect size was 0.988. Alpha level was set on 0.05 and power level on 80%. The estimated total sample size was 36 patients; with 18 patients within each group, and increased to be 20 patients in each group to avoid dropout.

2.6 Data analysis.

In the beginning, the data distribution normality was tested through the Shapiro-Wilk test. Baseline comparisons of patient’s demographic data between groups were performed using t-tests. Mixed MANOVA was performed to determine the main effect of time, the main effect of interventions, and the main interaction effects. Post-hoc tests using the Bonferroni corrections were done for the subsequent multiple comparisons. The significant point for all statistical analyses was set at p < .05. Statistical package for social studies (SPSS) version 25 for windows was used to conduct all analyses.

III. RESULTS

Forty patients met the inclusion criteria, joined the study and completed the study (dropout = 0). The characteristics of the patients were similar at the baseline (Table 1). During the treatment, no adverse effects were reported in both study and control groups.

Table (1): Baseline comparisons of the patients in both study and control groups.

<table>
<thead>
<tr>
<th></th>
<th>Study group mean ± SD</th>
<th>Control group mean ± SD</th>
<th>MD</th>
<th>T value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>58.40 ±4.12</td>
<td>56.20 ± 4.57</td>
<td>2.20</td>
<td>1.59</td>
<td>0.11a</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.75 ± 5.81</td>
<td>83.20 ± 6.71</td>
<td>0.45</td>
<td>-0.22</td>
<td>0.82a</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.40 ±7.47</td>
<td>181.20 ± 5.67</td>
<td>2.80</td>
<td>-1.33</td>
<td>0.19a</td>
</tr>
<tr>
<td>BMI(kg/m²)</td>
<td>26.05 ±2.04</td>
<td>25.32 ± 1.86</td>
<td>0.73</td>
<td>1.18</td>
<td>0.24a</td>
</tr>
<tr>
<td>HbA1c</td>
<td>7.66 ± 0.88</td>
<td>7.24 ± 0.45</td>
<td>0.415</td>
<td>-1.86</td>
<td>0.07a</td>
</tr>
<tr>
<td>Neuropathy disability score</td>
<td>6.95 ±0.82</td>
<td>7.25 ± 0.71</td>
<td>0.30</td>
<td>-1.22</td>
<td>0.22a</td>
</tr>
<tr>
<td>Duration of diabetes</td>
<td>13.05 ± 1.53</td>
<td>12.15 ± 1.59</td>
<td>0.90</td>
<td>1.81</td>
<td>0.07a</td>
</tr>
</tbody>
</table>

a: No significant difference; SD: Standard deviation; p-value: Significance level; BMI: body mass index.
Mixed MANOVA was performed to identify the treatment effect on degree of angular displacement error of active wrist extension, HGS and JTHFT of the right side in both groups. There was a significant interaction effect of treatment*time, a significant main effect of treatment, and a significant main effect time ($P < 0.05$).

**Within group analysis**

Statistically significant improvement was observed in the degree of angular displacement error of active wrist extension, HGS and JTHFT in both study and control group ($P < 0.05$). While the improvement was greater in study group in comparison with control group (table 2).

**Table (2): Within-group pairwise comparisons in both study and control groups.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Study group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-treatment</td>
<td>Post-treatment</td>
</tr>
<tr>
<td>Active wrist extension</td>
<td>6.1±1.71</td>
<td>2.55±1.31</td>
</tr>
<tr>
<td>Angular displacement error</td>
<td>4.95</td>
<td>3.17%</td>
</tr>
<tr>
<td>HGS</td>
<td>25.30±3.26</td>
<td>30.25±3.09</td>
</tr>
<tr>
<td></td>
<td>6.10</td>
<td>19.56%</td>
</tr>
<tr>
<td>JTHFT</td>
<td>66.9±12.43</td>
<td>35.55±10.08</td>
</tr>
<tr>
<td></td>
<td>7.67</td>
<td>46.8%</td>
</tr>
</tbody>
</table>

**SD**: Standard deviation; **MD**: Mean difference; **P**: Level of significance; **JTHFT**: Jebsen-Taylor Hand Function Test; **Hand grip strength; b**: Significant difference.

**Between group analysis**

No statistically significant difference was observed between measured variables (degree of angular displacement error of active wrist extension, HGS and JTHFT of the right side in both groups before treatment ($P > 0.05$). While post treatment there were statistically significant difference in all measured variables (degree of angular displacement error of active wrist extension, HGS and JTHFT of the right side in study group compared to control group as ($P < 0.05$) (table 3).
Table (3): Between groups pairwise comparisons for both study and control groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>95% Confidence Interval</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean±SD</td>
<td>MD</td>
</tr>
<tr>
<td>Study group</td>
<td>Control group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active wrist extension</td>
<td>6.1±1.71</td>
<td>5.15±1.632.26</td>
<td>0.95</td>
<td>0.080b</td>
</tr>
<tr>
<td>Angular displacement error</td>
<td>25.30±3.26</td>
<td>25.90±3.21</td>
<td>0.60</td>
<td>0.56c</td>
</tr>
<tr>
<td>HGS</td>
<td>66.9±12.43</td>
<td>68.30±13.97</td>
<td>1.40</td>
<td>0.74a</td>
</tr>
<tr>
<td>JTHFT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD: Standard deviation; MD: Mean difference; P: Level of significance; JTHFT: Jebsen-Taylor Hand Function Test; HGS: Hand grip strength; b: Significant difference; a: No significant difference.

IV. DISCUSSION

The benefits of hand exercises especially proprioceptive training for the wrist in patients with type 2 DPN has not been extensively studied, therefore this study was carried out to explain the effectiveness of hand exercises program on wrist proprioception, HGS and hand function in patients with type 2 DPN.

The findings of this study revealed that, the group receiving the hand exercises program showed a significant improvement in wrist proprioception, grip strength and hand function than the other group who receiving conventional physical therapy only.

The significant improvement in the group receiving the hand exercises program than the other group might be explained by the difficulty to isolate the sensory aspect of training from the motor one as the proprioception is closely related to movement. In fact, any form of motor learning is linked to proprioceptive processing e.g. visuomotor tasks like reaching for objects or throwing an object are considered a form of proprioceptive training and lead to acquisition of motor skills [30].

The findings of the current study are consistent with the findings of Can and Erdem [46] who performed a study to investigate whether wrist proprioceptive exercises is more effective than the conventional exercises for hand grip force sense, they concluded that the precision of wrist force reproduction may be improved via proprioceptive training. Also, proprioceptive training can improve the sensibility of grip force in normal subjects. So, they recommended the addition of proprioceptive exercises to the rehabilitation program for hand and wrist in clinical practice.

Moreover, Aman et al. [30] performed a systematic review article to clarify the idea of proprioceptive training; they concluded that training of proprioceptive system can lead to significant improvement in both somatosensory and sensorimotor function. The most useful types of training are those which use both passive and active

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movements with and without visual feedback. Also, the initial proof proposing that training of proprioceptive system stimulate the cortical reorganization which support the idea that proprioceptive training is an applicable method for enhancing sensorimotor function.

Rantanen et al. [49] & Leveille et al. [50] have reported decrease in HGS in patients with type 2 DM. However, Andersen et al. [51] & Andersen et al. [14] were against these studies, they reported that HGS is not affected in long-standing type 2 DM. The difference among mentioned studies can be attributed to the lack of grip strength record at baseline in the previous studies, which makes determining the change in hand grip strength after diabetes onset impossible.

Reduction in the grip strength in patients with DPN is related to poor glycemic control and increase in systemic inflammatory cytokines like tumor necrosis factor a (TNF-a) and interleukin-6 (IL-6) which have adverse effects on muscle function [52]. Also, Insulin resistance in patients with type 2 DM might be responsible for muscle weakness and, thus, the decrease in hand grip strength [53].

In the current study, there is a significant improvement in HGS and hand function in the study group in comparison with control group (p = 0.025, p=0.02 respectively). This improvement might be attributed to the effect of resistance training on muscle mass as the resistance training increase the muscle mass and thus the muscle volume available for the glucose uptake from blood [54]. It was found that the muscle mass play an important role in homeostasis of blood glucose, as higher fasting blood glucose and insulin levels is correlated with lower muscle mass in people without diabetes [55].

In patients with type 2 DM, resistance exercise decrease insulin resistance and glycosylated hemoglobin HbA1c [56] and improve the glycemic control. Also, resistance training is shown to improve muscle strength and endurance, promote flexibility and body composition, reduce the risk factors for cardiovascular disease, and lead to improvement in glucose tolerance and insulin sensitivity. Modifications to the type and/or intensity of the exercise could be necessary for the patients who developed diabetes complications [30, 31].

The findings of this study come in agreement with Thorat and Ganvir [32] who performed a study to explore the strength training effectiveness on hand function in patients with DPN. Grip strength was measured using hand dynamometer before and after treatment. Strength training was performed by spring hand dynamometer, squeeze ball and rubber band exercises. The results showed a significant improvement of grip strength and hand function after 4 weeks of strength training program and they concluded that grip strength training improved the hand function in DPN.

Similarly, Agbonlahor and Hammed [57] performed a study to determine the effect of a strength training program for 12 weeks on hand function in patients with type 2 DM. Hand grip strength was measured using electronic hand dynamometer and pinch strength was measured by mechanical pinch gauge. Measurement was performed beforehand after 12 weeks of strength training. The results showed that strength training program for 12 weeks had a significant effect on hand function in patients with type 2 DM.

Moreover, Geirsdottir et al.[58] evaluated the effect of resistance training for 12 weeks on muscle strength and physical function in healthy, prediabetic, and type 2 DM older people. They concluded that resistance exercise program for 12 weeks improved muscle strength and function in the three groups to the same extent.

The present study has some limitations. The main one was the lack of follow-up to determine the long term effects of hand exercises program on wrist proprioception, HGS and hand function in patients with type 2 DPN. In addition, the study results can’t be generalized to all patients in the whole world as the choice of the patients at first was represented as a convenient sample rather than a random sample of the whole population. Furthermore, the physiotherapist was not blinded as the interventions nature demand direct connection between both the physiotherapist and the patients.

V. CONCLUSION

Adding hand exercises program (proprioceptive training and strength training) to conventional physical therapy is necessary to restore wrist proprioception and improve HGS and hand function, in the patients with type 2 DPN. So, proprioceptive and hand strength training should be an essential strategies in rehabilitation of patients with type 2 DPN complaining of hand dysfunction.
Acknowledgments

Many thanks to all patients and the staff members of the Biodex isokinetic dynamometer for their cooperation in completion of this study.

Conflict of interest

The authors declare that there is no any conflict of interests regarding the publication of this paper.

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