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Acute effects of cold and muscle vibration on maximal grip strength and muscle endurance in normal subjects

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Summary
The objective of this study was to compare the acute effects of 10 minutes cold application and 50Hz, 90 seconds vibration of forearm muscles on maximum grip strength and muscle endurance in apparently healthy young adults. This within-subject factorial research study recruited eighty-nine subjects (49 males and 40 males) using a sample of convenience. Baseline maximum grip strength and endurance index were measured using a Jamar dynamometer. Cold and muscle vibration were applied within 48 hours interval to the forearm muscles of the subjects. Their grip strength and endurance index were measured; immediately, 5, and 10 minutes post-application of either stimuli. Data were analysed using independent t-test and one-way analysis of variance at 0.05 alpha. Results showed that neither vibration ($P>0.05$) nor cold ($P>0.05$) produced any significant effect on the maximum grip strength and the grip endurance at 5 and 10 minutes post application. The subjects however recorded significantly higher endurance index immediately post cold than they did immediately post vibration ($P<0.05$). We concluded that grip endurance was enhanced more by cold application than by muscle vibration. Cold rather than vibration may therefore be used to facilitate grip endurance during hand rehabilitation.

Keywords: *Acute, cold, vibration, grip strength, endurance*

Resume
L'objectif de cette étude était de comparer les effets aigu de 10 minutes dans l' application rhume et 50kz, 90 secondes de vibration des muscles de l'avant-bras sur la force maximum de poigne et l'endurance musculaire chez un jeune adulte apparemment sain. Ceci dans le cadre d'étude de recherche factoriel a recruté 49 homme et 40 femmes en utilisant un échantillon de pratique. La force maximum de poigne de base et l' indice d'endurance avait été mesure en utilisant un dynamométrie de Jamar. Le froid et la vibration musculaire on été appliqué en 48 heures d'intervalle aux muscles de l'avant-bras des sujets leur force de poigne et leur indice d'endurance ont été mesurés, immédiatement, 5 et 10 minutes post-application des deux stimuli les donnes avaient été analysées en utilisant le test indépendant T et une analyse en ligne de variance a 0,05 alpha. Les résultants ont monte que ni la vibration ($P>0,05$) ni le froid ($P>,05$) n'ont produit d'effet important sur la force de poigne maximum et l'endurance de poigne a 5 et 10 minutes post application. Les sujets ont cependant enregistre un indice d'endurance bien élevé immédiatement après le froid que, quand ils l'ont fait immédiatement après la vibration ($P<0,05$). Nous avons conclu que la poigne d'endurance avait été plus améliorée par l'application du froid que par la vibration musculaire, le froid plutot que la vibration serait donc utiliser pour faciliter la poigne d'endurance pendant la réhabilitation de la main.

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Introduction

Gripping is one of the most commonly employed activities of man's daily living [1] and grip strength measurement is one of the determinants of functional integrity of the hand [2]. Injury to the neuro-musculoskeletal system could affect the contractile ability of a muscle. This can lead to reduction in its strength and endurance, a condition that may necessitate physiotherapy. To help facilitate contraction and thereby enhance both muscular strength and endurance during rehabilitation of patients with these injuries, stimuli such as cold and muscle vibration are employed.

The physiologic effects of either cold or high frequency muscle vibration suggest that their respective use could improve strength and endurance. Sapenga *et al* [3] observed that the rate of metabolic deterioration progressively declined with decreasing temperature of muscle tissue to 10 degrees Celsius. They also noted that there was a significant acceleration in the rates of degradation of adenosine triphosphate and phosphocreatine and in the production of lactate at one degree Celsius. The rate of degradation of adenosine triphosphate in human ischemic muscle was also faster at one degree Celsius than at 10 degrees Celsius. This paradoxical response was suggested to be apparently due to a severe inhibition of the calcium pump of the sarcoplasmic reticulum of the muscle cell at temperatures of less than 5 degrees Celsius. The inhibition permits an efflux of calcium to the myofibrils, which stimulates both glycolysis and the degradation of adenosine triphosphate by myofibrillar adenosine triphosphatase [3].

There is however paucity of studies comparing how these two stimuli would affect muscle strength and endurance in normal individuals. The question we sought to answer in this study was: What would be the comparative effects of 10 minutes cold application and 50Hz, 90 sec-

onds forearm muscle vibration on maximum grip strength and endurance index in apparently healthy young adults?

Methodology

Design and setting:

This laboratory study employed a pre-experimental research design. Measurements on all subjects were carried out before and after introduction of both stimuli. There was an interval of 48 hours between applications of either stimulus.

Subjects Selection

One hundred and twenty subjects from among the clinical sciences students of the University of Ibadan, Nigeria, were selected using a convenience sampling technique. Their ages ranged from 19 to 30 years. The subjects had no known neurological abnormalities, no previous injury or on-going disorders of the upper extremity. They did not know the anticipated influence of the stimuli on their muscle strength and endurance. They all gave their informed consent to participate in the study.

Methods

Instruments

1. Body and Soul muscle vibrator (Body and Soul Inc, New York) with 50Hz frequency was used to apply vibratory stimulus to the muscles
2. Jamar Hand dynamometer (Stoelting Co, New York) was used to measure both the maximum grip strength and grip endurance index in kilogram force (Kgf).
3. Details Sport Timer stopwatch (Harvest Way Limited, New York) was used to record time in determining endurance index
4. Liquid paraffin was used to protect the skin against ice burn
5. Crushed ice provided the source of therapeutic cool ing
6. Towels were used to make ice pack for cooling.

Procedure for Data Collection:

Ethical approval was obtained from the University of Ibadan/University College Hospital Institutional Review Committee (Protocol number: UI/IRC/03/0020) before commencing on the study. The procedure was explained to the subjects and their informed consent was obtained before involving them in the study.

Subjects wore vest in order to ensure easy accessibility to their upper limb during the procedure and data collection. Although the subjects performed the same tests, to avoid data set, subjects were assigned into either group A or B in alternate order as they became available. Each subject in group A had vibration as the first test stimulus applied and 48 hours later the cold application was carried out while group B subjects had cold application as the first test stimulus and vibration was applied 48 hours later.

Measurements

We requested that the subjects did not participate in any strenuous physical exertion during the hour preceding their reporting for data collection. They were also allowed a ten-minute rest when they reported for data collection. These were done in order to avoid carry over fatigue from previous exertion to the study.

Baseline measurement: Each subject performed the initial (baseline) series of grip strength and endurance test, without introduction of any test stimulus, as follows:

Starting position: Subject was in a sitting position on a chair with his/her right arm resting on a pillow placed on the armrest. The shoulder was slightly adducted, elbow flexed to 90 degrees, forearm and wrist in neutral position, following the procedure of Alawale and Amusat [4]. We encouraged subjects to exert maximum grip on the dynamometer. The instruction was 'grip'. While the subject performed the task, one of the authors (MBF) noted the maximal reading on the dynamometer. This was recorded as the baseline grip strength value of the subjects in kgf. The time that elapsed for the maximal grip strength to fall to half its value was also recorded as the endurance index in seconds [5]. Each of the maximum grip strength and endurance test procedures was repeated after three minutes rest period. The average of the two readings for each variable was computed and recorded for data analysis.

After taking baseline measurements, a rest period of five minutes was allowed before applying the first stimulus-cold or vibration depending on the group (A or B) to which the individual subject belonged.

Muscle Vibration as a Stimulus:

Starting position was similar to that for baseline measurement, except that the forearm was supinated on a pillow for easy vibration of the muscle.

Procedure: The muscle vibrator was hand held and placed on the anterior aspect of the forearm muscle belly of the subject with moderate pressure, just enough to hold the vibrator in place. The vibrator was switched on for 90 seconds only. At the 90th second, the vibration procedure was terminated and the subject performed the immediate post-vibration grip strength and endurance test. This was repeated at the 5th and 10th minutes after the stoppage of the vibration procedure.

Cold as a stimulus:

Forty-eight (48) hours interval was allowed before the subject returned for test under the second stimulus.

Starting Position: This was as for the muscle vibration

Procedure: A thin film of liquid paraffin was applied to the anterior aspect of the subject's forearm as a protection against ice burn. Cold was applied to the forearm muscles using the ice pack method. Ice pack was made by wrapping crushed ice in 5 layers of towel thickness [5]. This

was applied to the anterior portion of the forearm covering from the wrist to the elbow for 10 minutes. After 10 minutes, the ice pack was removed and the grip strength and the endurance index were determined immediately, 5- Minutes and 10 minutes post cold application.

Treatment of Data

Descriptive statistics of mean and standard deviation were computed for all the parameters measured. One-way analysis of variance was used to compare the grip strength and endurance index values the 4 time frames and t-test was used to compare post stimuli application parameters of the subjects. Significance level was set at 0.05 alpha.

Results

Our results, as presented in table 1, showed that there was no significant difference in the baseline, immediate, 5 minutes and 10 minutes post vibration grip strength ($P>0.05$) and endurance index ($P> 0.05$) of the subjects. A trend was however observed in the grip endurance index across the four test time frames. There was an increase in the mean grip endurance value from baseline to immediate post, from immediate to 5 minutes post and a slight decrease from 5 minutes to 10 minutes post cold application.

Table 1: Comparison of baseline and each of the post vibration grip strength and endurance index of the subjects, across the four testing time frames using one way ANOVA

	Grip Strength (kgF) x ± S.D	Endurance Index (s) x ± SD
Baseline	34.52 ± 8.57	25.76 ± 9.38
Immediate post	33.93 ± 8.05	26.94± 11.71
5 minutes post	34.27 ± 7.27	26.60± 11.76
10 minutes post	33.26 ± 7.65	26.45± 12.58
f ratio	0.39	0.24
p level	0.76	0.87

Key:
KgF = Kilogramforce
S = Seconds

There was also no significant difference in the baseline, immediate 5 minutes and 10 minutes post cold application grip strength ($P>0.05$) and endurance index ($P>0.05$) as shown in Table 2. There was however a significant increase in the mean endurance index immediately post cold application when compared with the mean endurance index immediately post vibration ($P<0.05$) as shown in table 3. No significant difference was observed ($P>0.05$) when the immediate post vibration was compared to the immediate post cold application grip strength (Table 3).

Table 2: Comparison of baseline and each of the post cold application grip strength and endurance index of the subjects, across the four testing time frames using one - way ANOVA

	Grip strength (kgf) x ± S.D	Endurance index (s) x ± S.D
Baseline	34.36 ± 8.80	27.05 ± 10.93
Immediate post	34.00 ± 8.68	32.09 ± 15.64
5 minutes post	32.96 ± 7.84	33.02 ± 19.15
10 minutes post	33.42 ± 8.52	32.43 ± 21.18
f ratio	0.48	2.30
p level	0.69	0.07

Key:
KgF = Kilogramforce S = Seconds

Table 3: Comparison of immediate post vibration and immediate post cold grip strength and endurance index of the subjects using independent t-test (N=89).

	Grip Strength (KgF) x ± SD	Endurance Index(s) x ± SD
IPC	34.16 ± 8.76	32.06 ± 15.99
IPV	33.93 ± 8.05	26.94 ± 11.71
t-value	0.37	3.34*
p level	0.71	0.00

Key: IPC= Immediate post cold application
IPV=Immediate post vibration
KgF=Kilogramforce
S = Seconds
** Significant at p<0.05*

Discussion

While this is not a training study, our experience was that out of a total of 120 subjects recruited only 89 completed the study, indicating a 25% dropout rate. Some of the subjects did not report for the second half of the data collection, despite haven given their consent to participate and follow the scheduling of the data collection. Seven participants reported mild itching sensation during the application of the vibration to their forearm muscles and this experience lasted 3-5 minutes after the removal of the vibrator from their forearms.

We observed that vibration of the forearm muscle belly of the apparently healthy subjects did not cause any statistically significant difference in each of grip strength and endurance index before (baseline), immediately, 5 minutes and 10 minutes post-vibration. The findings of this present study are however in contrast to an earlier study

[6] which reported a significant increase in strength when extensor muscles of the forearm were vibrated. Study by Issurin *et al* [7] reported that vibratory stimulus caused an almost 50% increase in one repetition maximum compared with an average of 16% with conventional training and no gain for the control group [6]. It has also been found that the handgrip force of vibration exposed forest workers using chain saws was diminished in comparison with controls [8]. The non significant difference in post vibration grip strength as demonstrated in our study could be due to the fact that the frequency of vibration (50Hz) was low compared to the frequency of 120Hz used in the study by Curry and Clelland [6]. These authors had noted that the higher the frequency of vibration, the stronger the effect of the tonic vibratory reflex (TVR) generated and the greater the effect on muscles [6]. However a low frequency vibration (50 Hz) was used in this study, as low frequency vibrators are more readily available in Nigeria physiotherapy clinics than the higher frequency. The difference in muscle vibrators used and the type of muscle vibrated could also account for the difference in results we obtained compared with those previous studies.

Application of cold for 10 minutes to the forearm muscles did not significantly affect grip strength and endurance index in our study. An earlier study by Sanya and Bello [4] where cold was applied to the quadriceps muscles of normal subjects for 10 minutes and using the same method of application as used in the present study however showed a significant increase in quadriceps endurance index of their subjects immediately post and 15 minutes post-cold application [5].

We also observed no significant difference between the immediate post vibration and cold application grip strength. This implies that the two stimuli had no differential effect on the grip strength of the subjects. Cold application however produced a significantly higher immediate post application endurance index than vibration. This implies that cooling produced sufficient improvement in muscle endurance rather than the tonic-vibratory reflex produced by muscle vibration.

Based on our findings the following conclusions were drawn:

(a). 50Hz, 90seconds vibration did not have a statistically significant effect on grip strength and endurance index in apparently healthy young adults.

(b.) 10 minutes cold application did not have a significant effect on grip strength and endurance index in our subjects. However, application of cold for the same duration increased endurance index more than muscle vibration.

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