# 行政院國家科學委員會專題研究計畫 期中進度報告

## 發展協調障礙兒童步行時之肌電訊號分析與類神經網路應用(1/2)

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# 摘要

在學齡時期有一群兒童外表正常，沒有神經方面疾病、發展遲緩和智能不足，但動作發展上卻有著協調障礙存在，就稱爲發展協調障礙。美國精神醫學學會將之定義爲「可完成的動作和協調性顯著地遜於同等年齡和智商能力之兒童，以致嚴重地妨礙了理論上同年齡可完成的日常活動的症候群」。在日常生活中的各種活動中，最常使用到的節律性活動之一即爲走路，也是需要骨骼肌肉系統與神經系統互相密切配合，才有平穩且協調性的步行動作完成。肌電訊號量測提供步態分析中，肌肉收縮模式的了解。因此，本研究的目的爲研究發展協調障礙兒童在跑步機上走路時肌肉收縮的習慣性探討。目前有六位發展協調障礙兒童、六位疑似發展協調障礙兒童、及六位正常兒童爲受試者，利用表面電極，測量雙側臀大肌、股直肌、腿後肌、脛前肌、及腓長肌之肌電訊號，在跑步機上走 13 分鐘，收集每分鐘之前 15 秒資料，分析變異數比例作爲跑步機走路下肢肌肉收縮習慣性的指標，結果顯示發展協調障礙兒童之臀大肌變異數比例比疑似發展協調障礙兒童及正常兒童要來得高，而其他四條肌肉則沒有明顯差異。另外，正常兒童組在跑步機上走了九分鐘後，其變異數比例之波動性明顯降低，表示在跑步機走路之肌肉收縮已趨近穩定，而此現象在發展協調障礙兒童組並不明顯。本研究之結果，可以了解發展協調障礙兒童走路時的肌肉動作表現，對於發展協調障礙的診斷與治療上，可提供更進一步的參考資訊。


關鍵詞：發展協調障礙、肌電圖、習慣性

## Abstract

During the early school years, a number of children present with specific coordination problems and display poor perceptual-motor skills. This condition is recognized as developmental coordination disorder (DCD), a deficit in the development of motor skills that is not directly associated with any mental retardation or physical disorder. In order to better understand the neural mechanism of motor control for the children with DCD, it would be valuable to investigate the habituation for children with DCD during treadmill walking with the electromyography measurement of the muscles in lower extremity. Eighteen subjects, including six DCD children, 6 borderline DCD (DCDB) children and 6 children as control group, were recruited in this study. Ten surface EMG electrodes were used in this study. The medial gastrocnemius (MG), tibialis anterior (TA), rectus femoralis (RF), hamstring (HS) and gluteus maximum (GM) were measured bilaterally. The data were collected at the first 15 seconds of each minute within 13 minute treadmill walking. The variance ratio (VR) was estimated as an index of habituation. The VR values of GM muscle in DCD group are greater than those in DCDB and control groups, especially in dominant leg ($P<0.05$). However, for the other four muscles, RF, HS, TA and MG, there are no significant difference of VR values between DCD and control groups. Also, based on our findings, it was implied that after 9 minutes walking, the muscle performance of treadmill walking in normal group was substantially steady since the trend of the VR values was approaching non-fluctuation. However, this VR trend was still fluctuant after 9 minutes treadmill walking for the DCD and DCDB groups. These findings may provide additional information for the walking performance of the DCD children as well as the guideline for the clinical therapy.

Keywords: Developmental coordination disorder, Electromyography, Habituation

## Introduction

During the early school years, a number of children present with specific coordination problems and display poor perceptual-motor skills. Such children appear to have no physical disability but takes such as hand-writing, or intercepting moving objects highlight their difficulty. This condition is formally recognized as developmental coordination disorder (DCD) by the American Psychiatric Association (1987). DCD affects approximately 6% of children in Mainstream primary education. It is often associated with educational, social and emotional problems that may continue beyond adolescence. These children are physically awkward or clumsy and slow to learn motor skills but this cannot be explained by intellectual deficits or identifiable physical or neurological disorders. These children are identified after referral for perceptural-motor intervention (Hulme, 1984; Hoehn, 1994) or by screening of the population of school children using a battery of tests (Mon-Williams, 1994). Children who are clumsy or have coordination problems early in life may continue to have motor problems as teenagers and some may have other developmental consequences such as poor academic outcome or low self-esteem (Henderson, 1993).

The act of walking is the fundamental to the performance of human lower extremity. It is also the most frequently used rhythmic exercise in everyday living. Also, human ambulation is one of the basic components of independent functioning that is commonly affected by either disease progress or injury. A mature walking needs intimate cooperation and proper function of nerve along with musculoskeletal system. In gait analysis, electromyography (EMG) provides researchers a reasonable way of accessing the muscle synergy pattern during locomotion. In order to better understand the muscle contraction of lower extremities for the children with DCD, it would be greatly valuable to investigate the characteristics of muscle contraction pattern for children with DCD during walking. Therefore, the purposes of this study are to study the habituation of EMG signal for the children with DCD during walking.

## Methods

### Subjects

The subjects of eighteen children, with six children of DCD, six children of borderline DCD (DCDB) and six children of control group, were recruited in this study. The control group was matched on school grade, age and non-verbal intelligence. A range of possible clumsy and control subjects were recruited from one elementary school in Taichung city. The Movement Assessment Battery for Children (Movement ABC; Henderson et al., 1992) was used to identify children whose motor functioning is impaired, such as children with DCD. Basically, Movement ABC consists of three clusters of test, including manual dexterity, ball skill and balance. The total score summarizes performance on all eight items and is interpreted in terms of age-related norms. The children whose total score was greater than 13 were classified as DCD group. Those whose scores were between 11 and 13 were classified as DCDB group. Those whose scores were less than 11 were classified as normal group. Any child with neurological or musculoskeletal deficit was excluded in this study. The basic data of these eighteen subjects were summarized in Table 1.

### Experimental Protocol

Each subject was asked to walk on a speed-controlled treadmill. Treadmill walking was performed for thirteen minutes at their most comfortable walking speed. Each subject was allowed to preliminarily walk on treadmill for 30 seconds to be familiar with the use of treadmill. The data were collected at the first 15 seconds of each minute. Therefore, there were 14 sets of EMG data collected within 13 minute treadmill walking.

The EMG activities of five main muscle groups in the lower extremities were measured bilaterally. The medial gastrocnemius (MG), tibialis anterior (TA), rectus femoralis (RF), hamstring (HS) and gluteus maximum (GM) were measured in this study. The surface electrodes were used as a non-invasive approach of data collection. The footswitch was used for the phase determination in gait cycle. The footswitch was placed on the plantar aspect of the foot, including the heel, first metatarsal head, fifth metatarsal head and big toe. MA 300 Electromyography measurement system (Motion Lab System, Inc., LA, USA) was utilized to collect data, control the synchronization between EMG signal and footswitch and transfer the digital data onto personal computer. The sampling frequency of data collection is 960 Hz.

**Data Analysis**

The original raw EMG signals were processed to a standard form, linear envelope. The raw EMG signals were filtered with a bandpass filter (cutoff frequency 40 Hz-400 Hz) to remove motion artifact and environment noise. Then full-wave rectification of filtered raw data was performed. An linear envelop was rendered with an integrator, corresponding to low pass filter with cutoff frequency at 8 Hz, to represent a meaningful profile of muscle activity. In addition, the EMG of different trial will be normalized in time-based points to reduce variation of unequal data segmentation and the whole movement cycle was expressed in 100%.

In order to determine the steady state for treadmill walking, variance ratio (VR), was developed in this study. The VRs of five examined muscle groups, both dominant and non-dominant, were calculated using the following equation.

$$VR = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n}(X_{ij} - \overline{X}_i)^2 / (k(n-1))}{\sum_{i=1}^{k}\sum_{j=1}^{n}(X_{ij} - \overline{X})^2 / (kn-1)}$$

where $k$ is the number of data point, $n$ is the number of average cycle, the $X_{ij}$ is the value of the $j$th EMG signal at the time point $i$, $\overline{X}_i$ is the average of the EMG values at the point $i$ averaged $j$ realization of the experiment, and $\overline{X}$ is the grand mean of the averaged EMG signal.

## Results and Discussion

EMG signals represent the motor unit action potential of the muscle during muscle contraction. The values after signal processing indicate the dynamic muscular activities during walking movement. The basic assumption of habituation process in terms of motor control is that proper practicing makes voluntary movement more accurate and less variant. Since the subjects have learned to control the examined muscle group habitually, the variance ratio of the EMG linear envelope is supposed to be reduced to a minimal level without significant fluctuation. The habituation study is based on the constancy of the dynamic EMG signals at the selected intervals during treadmill walking. In this study, a steady treadmill walking is defined as an acceptable VR without abrupt fluctuation. The EMG pattern of a steady state should be similar from stride to stride which indicates a tendency of decreasing VR. The VR values for each muscle group were shown in Figures 1. The VR values of GM muscle in DCD group are greater than those in DCDB and control groups, especially in dominant (right) leg ($P<0.05$). The VR values of RF muscle in DCD group is less than those in DCDB and control groups, especially in dominant leg. However, for the other three muscles, HS, TA and MG, there are no significant difference of VR values between DCD and control groups.

The mean VR values of all muscles within 13-minute treadmill walking were shown in figure 2. It was implied that after 9 minutes walking, the muscle performance of treadmill walking in normal group was substantially steady since the trend of the VR values was approaching non-fluctuation and lower than the other two groups. Moreover, the mean VR values of each muscle and its corresponding 95% confidence intervals were shown in figure 3. Apparently, the VR values of both examined GM muscle groups were substantially lower with mean value around 0.4 to 0.6 for both legs. On the other hand, the VR values of the other four muscles, the RF, the HS, the TA and the MG, were much higher ranging from 0.6 to 0.8. It was implied that greater variation of these four muscles were needed during treadmill walking. As walking was believed to be a habituated motor behavior, the VR of floor walking was a reasonable criterion to evaluate the repeatability of the linear envelope during treadmill walking.

In gait studies, minor importance has been generally given to the aspect of habituation. Arsenault et al. (1986) conducted to obtain information on the number of strides of EMG data needed per subject in a gait study. The linear envelope of the EMG, normalized in time and amplitude, demonstrated a very high level of stability for a given subject, relative to the variability that was found across subjects. In our study, the data of six continuous strides were collected for every minute during 13 minute treadmill walking. The VR values of the five muscle groups in lower extremity were between 0.6 to 0.8. The high VR values in our study may be resulting from the different walking pattern between adults and children, and the difference between the floor walking and treadmill walking.

## Self-Evaluation

A personal designed program written in Matlab language for estimating the VR trend have been developed for the evaluation of the treadmill walking in the DCD, DCDB and normal groups. We also have finished the programs to derive the linear envelope of the EMG signals during a gait cycle. EMG data from three groups of subjects, DCD, DCDB and normal groups have been collected and still ongoing. The children who have been classified as DCD group have been treated for proper physical therapy and will be retested with the same protocol to see if any EMG parameter changed and any motor performance improved in the next year. Partial results in this preliminary study will be presented in conference of biomedical engineering in Nov. 2003. Also, the artificial neural model will be developed in the second year project to classify the different groups of children.

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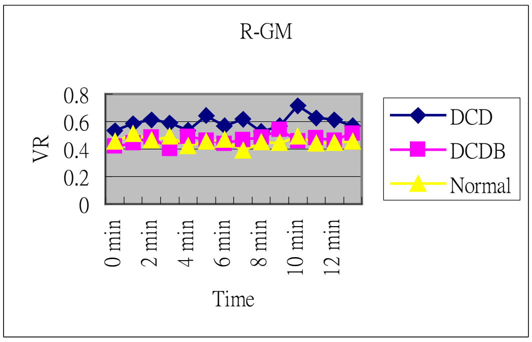
Table 1: Basic data of subjects recruited in this study (SD: standard deviation)

| Subject Type | DCD | DCDB | Normal |
|---|---|---|---|
| Subject Number (Male, Female) | 6 (2,4) | 6 (3,3) | 6 (2,4) |
| Age | 9.83 (range: 9-11) | 10 (range: 9-11) | 10 (range: 10-10) |
| Body Weight (kg) | 33.45 (range: 21-46) | 39.83 (range: 26-61) | 30.75 (range: 25-43) |
| Body Length (cm) | 135.50 (range: 120-142) | 138.83 (range: 128-149) | 135.83 (range: 128-142) |
| Treadmill Speed (m/sec) | 1.32 (range: 1.1-1.5) | 1.35 (range: 1.1-1.5) | 1.48 (range: 1.2-1.7) |
| Movement ABC Total Score (SD) | 15.58 (1.36) | 12.25 (0.88) | 3.92 (1.28) |
| Manual Dexterity Score (SD) | 8.25 (1.44) | 4.42 (2.08) | 3.92 (1.28) |
| Balance Score (SD) | 3.00 (1.76) | 2.75 (0.53) | 2.00 (1.64) |
| Ball Skill Score (SD) | 3.17 (2.04) | 67 (2.50) | 0.50 (0.84) |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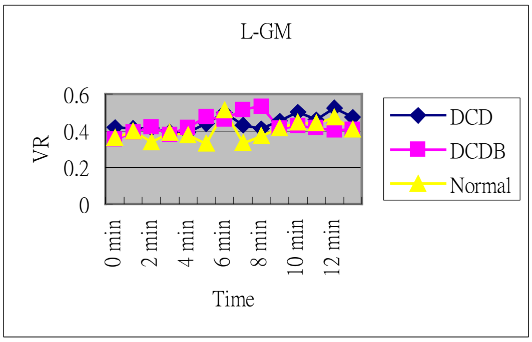
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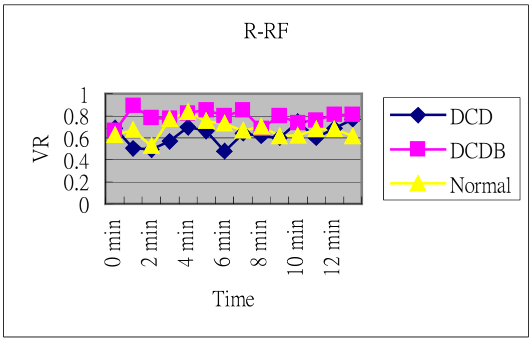
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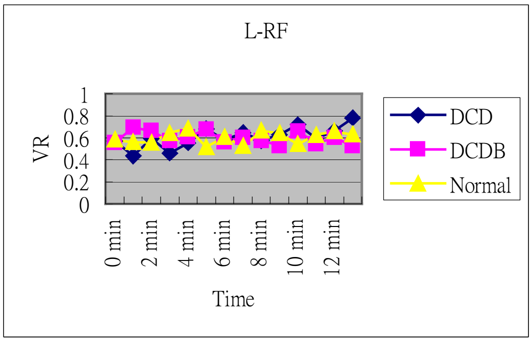
DCD
DCDB
Normal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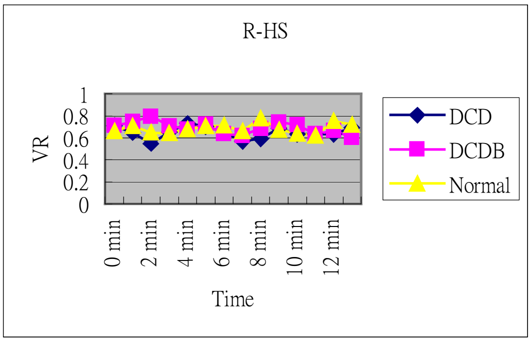
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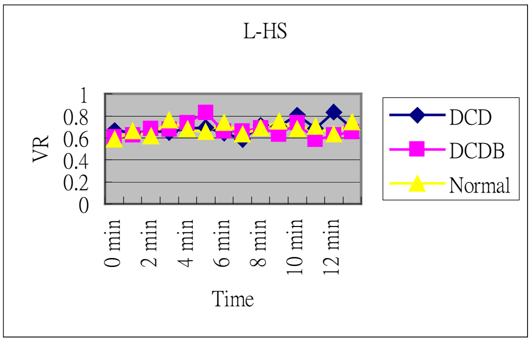
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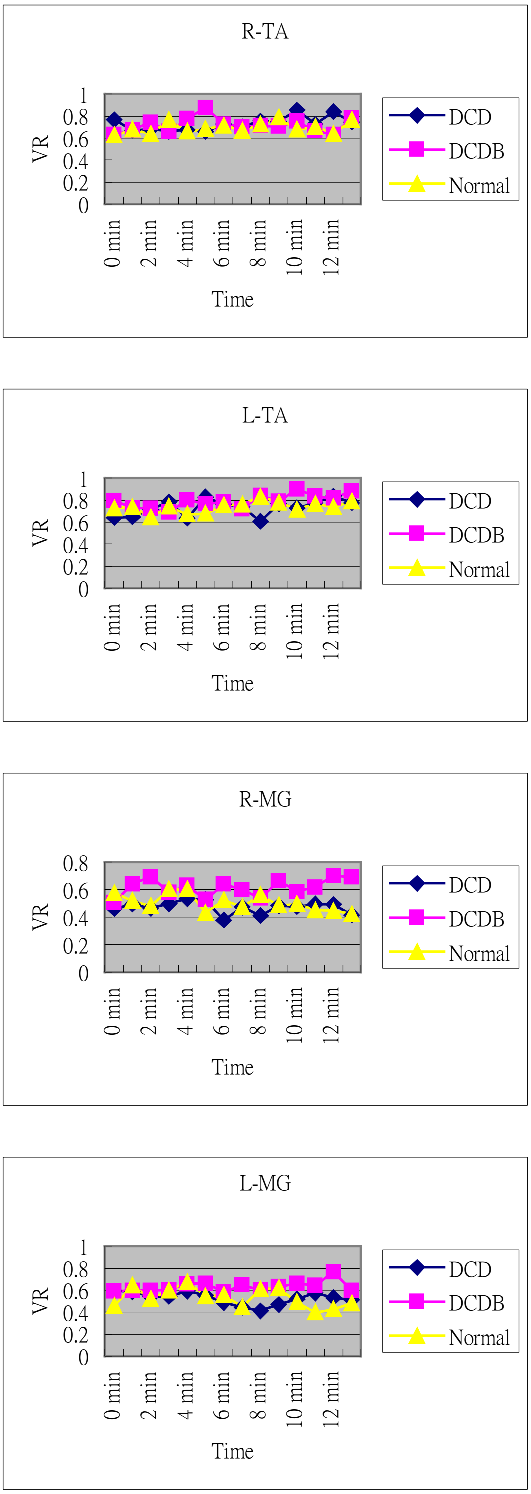



Fig 1: VR values of treadmill walking for DCD, DCDB and normal groups during 13 minutes treadmill walking (R: right side; L: left side; GM: gluteus maximum; RF: rectus femroalis; HS: hamstrings; TA: tibialis anterior; MG: medial gastrocnemius)

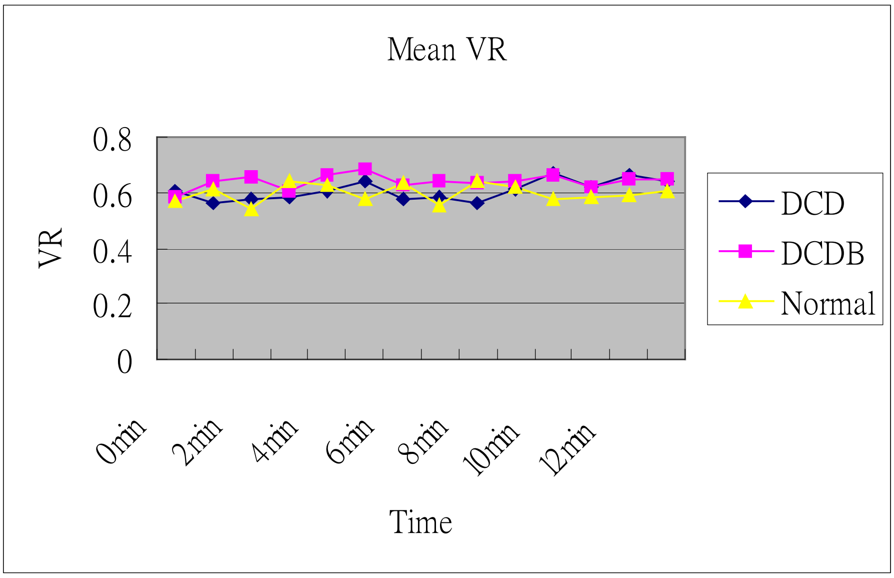
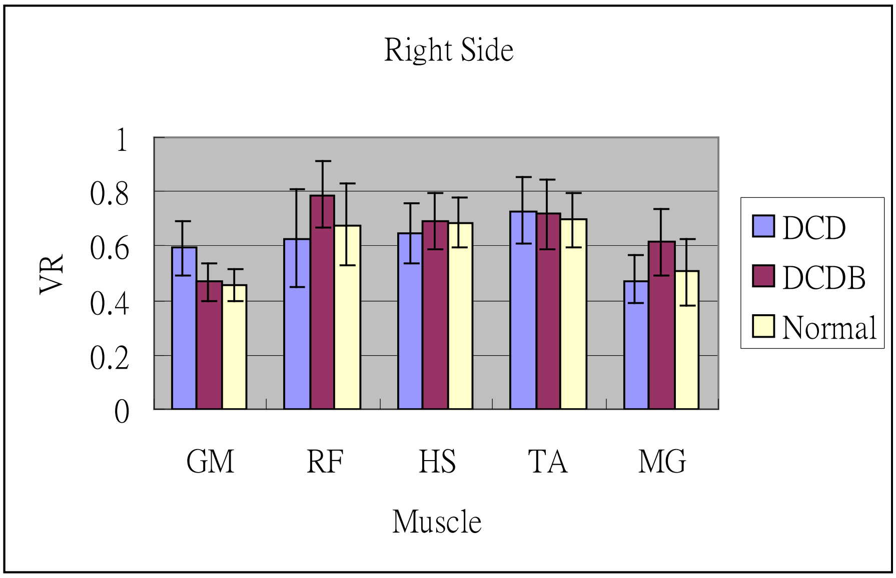



Fig 2: Mean VR values of all muscles for DCD, DCDB and normal groups during 13 minute treadmill walking



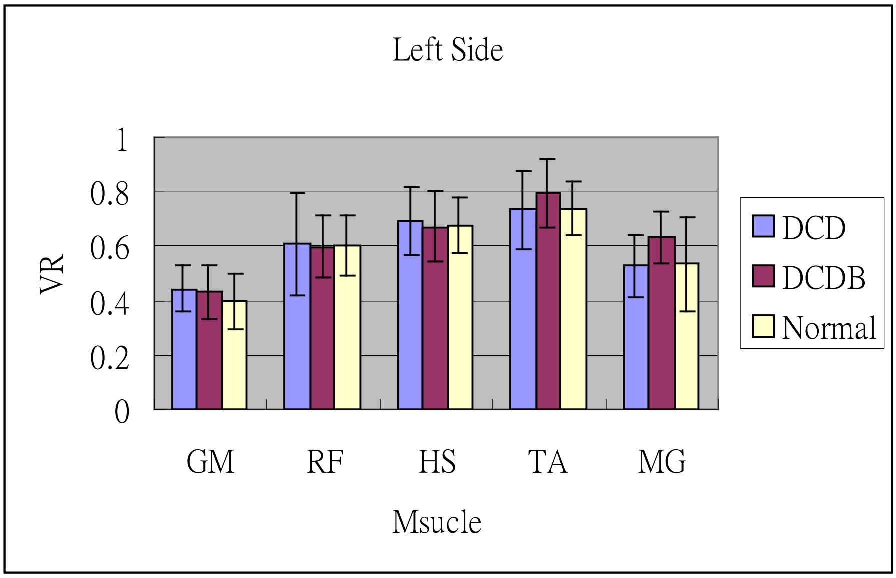




Fig 3: The mean VR values for different muscle groups. Error bar denotes the 95% confidence interval. (GM: gluteus maximum; RF: rectus femroalis; HS: hamstrings; TA: tibialis anterior; MG: medial gastrocnemius)