Gait Analysis in Normal Adults

— Agonist-Antagonist EMG Ratio —

by

Tomitaro Akiyama, Hiroyuki Nakano, Toshiya Tsurusaki,
Shigeru Inokuchi and Minoru Okino

Allied Medical Sciencec, Nagasaki University

There have been many reports concerning electromyographic (EMG) study on gait in normal adults, and the typical pattern of the muscular activity at gait is well known. However, the muscular actuvuty changes by step and individual difference is great. In order to apprehend more objectively the reciprocal muscular activity of the agonist-antagonist muscles at gait, the ratio of these muscle activities at gait in normal adults and infants was analyzed using the agonist-antagonist EMG ratio.

Subjects

The subjects were 20 healthy adults (10 males and 10 females) at age 20.1 ± 1.1 years (male, 19.9 ± 1.2 ; female, 20.7 ± 0.6). In addition, three normal infants were examined longitudinally from the neonatal period to age 1.5 years in terms of EMG at primary walking, propping and independent walking.

Methods

The myoelectric activity of the right tibialis anterior (TA) and the right triceps surae (TS) were recorded using surface electrodes during their free walking. The walking cycle was confirmed by foot switch. For each subject, muscular activity of 10 strides was integrated at each 10 msec for each stride, and the integrated waves of the TA and TS were sought by averaging the integrated value for 10 strides. The maximum muscular activity of each muscle was assigned as 100% and TA/TS ratio was calculated. The TA/TS ratio wave form thus obtained was compared with the forward-backward component and the vertical component of the ground reaction force at the measuring points. Time element was standardized using 1 stride as 100%.

Results

The TA/TS ratiograms in 20 healthy adults in relation to their walking cycle and to the forward-backward component of the ground reaction force are shown in Fig. 1 and Fig. 2 respectively.

The TA/TS ratiogram of gait in normal adults was divided into TA phase and TS phase. In relation to the foot switch, the peak of TA phase was observed between heel strike and foot flat and the peak of TS phase between heel off and toe off. In relation to the forward-backward component of the ground reaction force, the peak of TA phase was observed at the first half of the deceleration phase and the peak of TS phase

at the acceleration phase. In relation to the vertical component, and the peak of TA phase was immediately before the first peak of the vertical component and the peak of TS was at the second peak of the vertical component. The walking cycle % time and TA/TS ratio at the measuring points of forward-backward component and vertical component are shown in Table 1.

In the EMG in primary walking of a neonate, co-contraction of agonist-antagonist muscles was observed at the stance phase, and the TA/TS ratio fluctuated between the TA and TS phases with value 1 as the center. Prominent muscular activity of the tibialis anterior was noted at the swing phase and before floor contact. This was an immature reflexive gait in that the swing phase was short compared to the stance phase and that the upper body and trunk did not participate in the walking.

In the EMG findings at age 6 months, co-contraction at the stance phase was still prominent as in the primary walking, but the muscular activity of the tibialis anterior before floor contacting to the stance phase was purposeful. The swing phase was short (approximately 25%) as in the neonatal period, but the cadence was 40 which was twice as fast as that in the neonatal period.

In the EMG findings in high guard walking at age 12 months, reciprocal muscular activity was observed and the TA and TS phases became distinct. However, the center of gravity was not stable showing heel-toe-heel-toe and co-contraction was also observed at the stance phase. Because of unstable walking, the swing phase was as short as 10% and cadence was 88.

In the EMG findings in medium guard walking at age 1 year and 1 month, reciprocal muscular activity became more prominent. The stance and swing phases became stable, each being 50%. However, cadence was as fast as 180. Co-contraction of the tibialis anterior and triceps surae at the stance phase continued to be present.

At age 18 months, reciprocal walking became available, resulting in stable walking. In the EMG findings, the TA and TS phases became distinct and the pattern of walking resembled that of adults.

Discussion

The ratio of action potential of the tibialis anterior and triceps surae (TA/TS ratio) in walking was sought and radiograms were drawn. The muscular activity in normal walking was divided into TA and TS phases. The TA phase is a phase where the tibialis anterior shows a greater muscular activity than does the triceps surae, and the TA/TS ratio is 1 or more. The ratio is less than 1 in the TS phase.

The TA and TS phases in relation to the walking cycle and the ground reaction force showed the same pattern of muscular activity as reported by investigators^{3,4}. The reading of TA/TS radiogram has facilitated the apprehension of reciprocal activity compared to the real time reading of the electromyogram.

In normal gait in adults, well-controlled reciprocal muscular activity makes tactful walking possible. On the other hand, immature reciprocal muscular activity in infants and impaired muscular activity in various diseases induce a disorder in TA/TS radiogram.

The basic program of human gait is incorporated in the spinal cord and its driving program is in the brain stem. The process to acquire bipedal gait is a process to integrate these programs under the control of the cerebral cortex. Gait requires the development of antigravitic postural reaction for the maintenance of standing position and the maturity of reciprocal mechanism.

In the primary walking of neonate, co-contraction of the tibialis anterior and triceps surae at the stance phase was prominent, although there was observed a bipedal gait-like pattern with dominant muscular activity of the tibialis anterior before floor contact. At the stage of medium guard gait, reciprocal muscular activity developed but co-contraction due to immature postural reaction still remained.

Thus, the agonist-antagonist EMG ratio method makes it possible to assess reciprocal muscular activity more accurately, and it will be applied to gait assessment in various diseases.

Conclusion

1. The muscular activity in normal gait was divided into TA phase and TS phase.
2. The peak of the TA phase was observed between heel strike and foot flat, conforming with the first half of the deceleration phase of the ground reaction force.
3. The peak of the TS phase was between heel off and toe off, conforming the acceleration phase of the ground reaction force.
4. Co-contraction was prominent in primary walking of neonate and immature gait during the developmental process.
5. The gait pattern in the TA/TS ratiogram at age 18 months became similar to a normal ratiogram of adults.

References

1. Forssberg H. : Ontogeny of human locomotor control I. Infant stepping, supported locomotion and transition to independent locomotion. *Exp. Brain Res.*, 57 : 480-493, 1985
2. Fujita M. : Role of the metatarsophalanbeal (MTP) joints of the foot in level walking. *J. Jpn. Orthop. Ass.* 59 : 985-997, 1985
3. Suzuki R. : Methods of gait analysis and their clinical application. *Bull. Jpn. sci. prosthetics & orthotics* 1 : 75-81, 1985 (Japanese)
4. Tsurumi N. : An electromyographic study on the gait of children. *J. Jpn. Orthop. Ass.* 43 : 611-628, 1969 (Japanese)

Table 1 : % Time and TA/TS ratio at the measuring points

	% Time	TA/TS ratio
Z1	15.4	1.7
Z2	47.2	0.3
Z0	28.8	0.9
Toe off	65.5	1.0
X0	34.1	0.9

Z1 : The point of the peaks in the deceleration

Z2 : The point of the peks in the acceleration

Z0 : The point of the valley of Z1 and Z2

X0 : The point at which the forward component changed to the backward component

Fig. 1 TA/TS ratiogram in walking cycle

Fig. 2 TA/TS ratiogram and forward-backward component of the ground reaction force

Fig. 3 Primary walking (neonate)

Fig. 4 Reciprocal walking (1 year 6 months)

〈和文抄録〉

正常成人の歩行分析

—主動筋—拮抗筋筋活動電位相対比率法—

長崎大学医療技術短期大学部

穂山 富太郎・中野 裕之

鶴崎 俊哉・井口 茂

沖野 実

目的 歩行時の相反性筋活動をより客観的に把握する目的で、筋活動電位相対比率法を用いて拮抗筋間の相対比の分析を行なった。

方法 健康成人 20 名 (男 10 名, 女 10 名) を対象に、右前脛骨筋 (TA)、右大腿三頭筋 (TS) に表面電極を貼付し、自由歩行させて筋活動電位を導出し、その積

分値から一歩行周期の TA/TS 比を求めた。同時に測定した床反力の特性点、時間因子と関連して TA/TS 比を分析した。

さらに、3 人の正常児について、初期歩行、支持歩行、独歩の歩行筋電図を各児経時的にとり、TA/TS 比を求めた。

結果 相対比曲線は TA 相と TS 相に分かれた。TA 相のピークは Heel strike から Foot flat にかけて、床反力との対比では制動期前半に一致してみられた。TS 相のピークは Heel off と Toe off の間、床反力との対

比では駆動期に一致してみられた。初期歩行、支持歩行では同時収縮期が長く、1 才半で相反性筋活動が顕著となり成人の歩行パターンに近似してきた。