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行政院國家科學委員會補助專題研究計畫成果報告

皮膚標記移動誤差對臨床步態分析結果之影響

計畫類別：☑個別型計畫　□整合型計畫

計畫編號：NSC 89－2320－B－002－166－M08

執行期間：88年 8月 1日至89年 7月 31日

計畫主持人：呂東武　國立台灣大學醫學工程學研究所

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Influence of skin movement artefacts on the results of clinical gait analysis

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一、中文摘要

步態或動作分析之廣泛運用於患有骨骼肌肉系統疾病病人之診斷以及治療的規劃與評估仍然有限，主要係因其量測之可靠度尚未達標準，特別是在冠狀面與橫切面之量測值誤差仍大。目前常用的動作分析系統均使用皮膚標記，惟皮膚與骨頭相對的移動造成量測之誤差(皮膚移動誤差)甚巨。因此，減少皮膚移動誤差對此二面計算所得之關節運動的影響將可改善步態分析所得資料之品質以利擴展其臨床之應用。傳統方法將各肢段個別處理，並未考慮加入關節之限制條件，因而造成明顯的人為的關節移位，主要是因為皮膚移動誤差。本研究發展一下肢電腦模型，利用關節之限制條件以及全面性誤差補償機制，針對皮膚標記移動誤差做整體的最佳化，並經裝有骨外固定器病人實驗証明可顯著減低皮膚移動誤差，增加各關節之軸向旋轉及內縮與外展角度之精確度。計算所得關節合力矩亦比傳統方法精確。此一新發展的系統性方法改善了傳統作法的缺點，降低皮膚移動誤差對步態分析所得數據之影響，並去除關節不合理位移之情形，增進了步態分析之臨床應用可靠度。不僅有助推廣步態分析之臨床應用，更可促進相關領域之發展。

關鍵詞：步態分析，皮膚移動誤差，電腦模型，廣義最佳化，模型驗証，外固定器

Abstract

Widespread use of gait or motion analysis in the diagnosis of patients with locomotor pathology and the subsequent planning and assessment of treatment has been limited because of its reliability, particularly in evaluating frontal and transverse plane components. In skin marker based gait analysis systems, skin movement artefacts have been shown to affect the accuracy of calculated joint kinematics. Therefore, reduction of the effects of skin movement artefacts in the two planes will improve the quality of gait analysis data for clinical purposes. Traditional methods treat body segments separately without imposing joint constraints, resulting in apparent artefactual joint dislocations or inaccurate limb positions, predominately due to skin movement artifacts. In the present study, a mathematical model of the pelvis-leg apparatus coupled with a new method called Global Optimisation Method (GOM), which considers skin movement artefacts and imposes joint constraints, has been developed and has been shown, through experiments on patients with external fxators, to be superior to other traditional methods. The present study provides a better understanding of skin movement patterns in human, improves the accuracy and reliability of gait analysis results and helps promote the use of the clinical gait analysis techniques for the diagnosis and the subsequent planning and assessment of treatment of patients with neuromusculoskeletal pathology.

Keywords: Gait analysis, skin movement artefacts, computer model, global

optimisation, model validation, external fixator.

二、緣由與目的

Widespread use of gait or motion analysis in the diagnosis of patients with locomotor pathology and the subsequent planning and assessment of treatment has been limited because of its reliability, particularly in evaluating frontal and transverse plane components. This is critical because, in patients with pathological gait, such as children with cerebral palsy, abnormalities occur essentially in these planes. In skin marker based gait analysis systems, skin movement artefacts have been shown to affect the accuracy of calculated joint kinematics much more in the frontal and transverse planes than in the sagittal plane. Therefore, reduction of the effects of skin movement artefacts in the two planes will improve the quality of gait analysis data for clinical purposes.

In order to solve the problem of skin movement artefacts in clinical gait analysis, it is necessary to understand first the movement patterns of skin markers relative to the underlying bone. A study on adults has been reported in the literature (Cappozzo, et al., 1996). Similar study in children, however, has not appeared. This is a major limitation as children with neuromusculoskeletal pathology have been the major population receiving gait analysis. In calculating body kinematics and kinetics from skin marker coordinates, traditional methods treat body segments separately without imposing joint constraints, resulting in apparent artefactual joint dislocations or inaccurate limb positions (Apkarian et al., 1989; Chèze et al., 1995; Challis, 1995; Cappello, *et al*., 1996). Skin movement artefacts are either ignored or not dealt with effectively. A new method called Global Optimisation Method (GOM), which considers skin movement artefacts and imposes joint constraints, has been developed by the main applicant (Lu and O'Connor, 1999) and has been shown, using computer experiments, to be superior to other traditional methods. Data from living subjects are needed to provide a further quantitative comparison and experimental validation.

The goals of the project were (1) to investigate the skin movement patterns of the bony landmarks, commonly used in clinical gait analysis, in children and their difference with those in adults, (2) to study the influence of skin movement artefacts on gait analysis results, (3) to compare the performance of various methods in reducing skin movement artefacts, and (4) to develop a computer model of the human locomotor system, in combination with the best method found in (3), for use in clinical gait analysis.

三、研究方法

Four patients treated for femoral or tibial fracture with unilateral external fixators were recruited to participate in the present study with informed consent. In a gait laboratory, passive infrared retroreflective markers were attached to the bony landmarks of the pelvis-leg segments, namely the ASIS's, PSIS's, greater trochanter (GT), medial and later epicondyles (FC), head of fibula, medial and lateral malleoli, navicular tuberosity and heel. Four markers were also placed on the external fixation devices for the description of the spatial positions of the fixators (thus the bones) and the skin marker frames. To study the magnitudes and patterns of skin movement artefacts during functional activities, patients performed level walking, rising up from chair and stair climbing. A video-based motion data acquisition system, Vicon 370 (Oxford Metrics Ltd., Oxford, England), was used to record the three-dimensional coordinates of the markers for subsequent analysis. Two forceplates (AMTI, Mass., U.S.A.) were used to measure the ground reaction forces.

Gait variables calculated from external fixator marker coordinates represent the best values one can get with the system. Therefore, they provide a basis for the quantification of the magnitudes and patterns of skin movement artefacts and for the comparison of the performance of GOM and other traditional methods, namely direct method (DM), segmental optimization method (SOM) and top-down approach (TA), in reducing skin movement artefacts in calculations using skin marker coordinates. For the study of the effects of skin movement artefacts on the calculated kinematic geometry of the musculoskeletal system and joint kinetics, a model of the human locomotor system was developed.

四、結果與討論

Maximum magnitudes of marker skin movement of the four bony landmarks on the thigh segment in children were found to be smaller than those in adults but significant in the determination of the gait variables (Table 1). Without joint constraints, traditional methods created apparent artefactual dislocations at joints (Fig. 1a). With GOM, joint dislocation was not present and the errors in the calculated joint positions were significantly less than those calculated using traditional methods (Fig. 1b). The differences between the calculated and true position and orientation of the femur in terms of the translation vector and rotation matrix are shown in Fig. 2. The GOM produced the best results in both the translation vector and rotation matrix. Table 2 summarizes the percentage errors of the calculated moments at the hip and the knee for the four methods. Among the methods, the GOM again predicted results closest to those calculated from the external fixators. Other methods may have huge errors as much as 70% of the joint moment.

The results of the study suggest that geometrical and mechanical variables of the locomotor system during gait are sensitive to skin movement artefacts and that GOM is effective in reducing these effects. It not only provides a way of imposing joint constraints into skin marker based models but also takes the full advantage of these joint models in controlling relative motion of body segments. GOM assumes that each joint is properly modelled and correctly aligned with the adjacent segments. The present study suggests that the GOM will contribute to the improvement of the reliability of gait analysis results and thus the widespread use of gait analysis for clinical purposes.

五、計畫成果自評

The research project was carried out according to the original plan except that fewer patients than planned were recruited due to the limited availability of required patients. Nonetheless, we have achieved the goals set out at the beginning of the project. The skin movement magnitudes of the typical bony landmarks in children were found to be less than those of adults as expected. A model of the lower limb coupled with the Global Optimisation Method (GOM) was developed and was shown to produce results closest to those obtained by the external fixators, compared with other traditional methods. Two abstracts describing the results have been accepted for presentation at international conferences and three papers are under preparation for publication in international journals.

The study provides a better understanding of skin movement patterns in human, improves the accuracy and reliability of gait analysis results and helps promote the use of the clinical gait analysis techniques for the diagnosis and the subsequent planning and assessment of treatment of patients with neuromusculoskeletal pathology.

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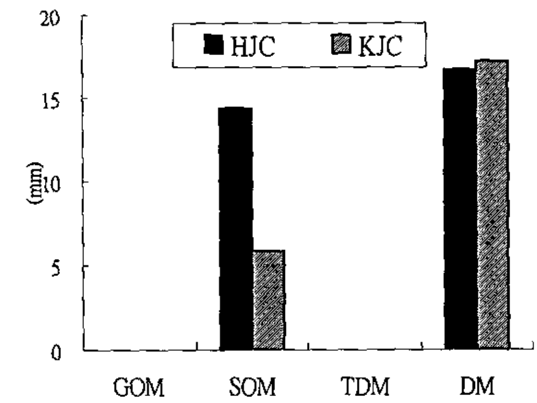
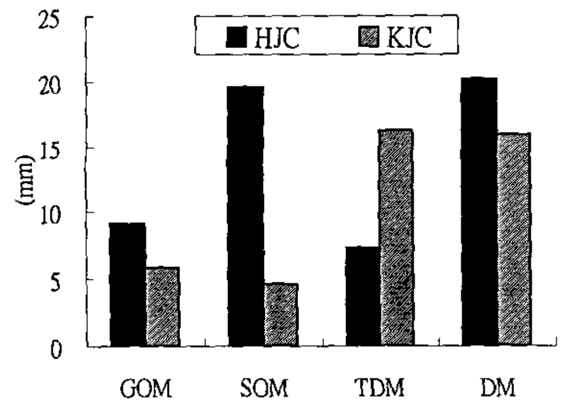


(a)



(b)

Fig. 1. (a) Ensemble time-averaged values of joint dislocation at the hip and knee for GOM, SOM, TDM and DM. (b) Ensemble time-averaged values of the distances between the calculated and true joint positions. (HJC: hip joint center; KJC: knee joint center)

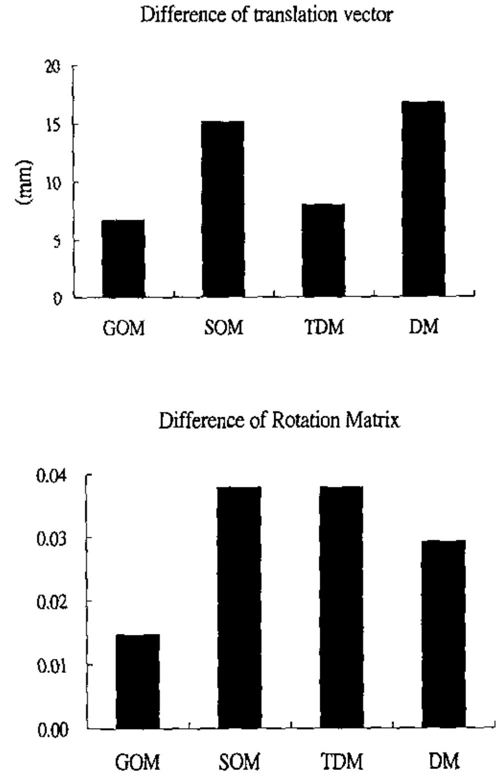


Fig. 2. Ensemble time-averaged differences of the origin vector and rotation matrix of the thigh coordinate system for the four methods.

Table 1. Maximum skin movement artifacts of the four markers on the thigh segment.

(mm)	X	Y	Z
GT	44.0	26.3	27.6
Mid Thigh	25.6	18.3	5.5
RLFC	-2.4	14.3	2.0
RMFC	25.8	9.9	7.8

Table 2. Percent error of time-averaged hip and knee joint moments.

	GOM	SOM	TDM	DM
Hip				
Add/Abd	13.24	20.53	32.80	16.76
Flex/Ext	22.96	64.35	75.83	69.11
IR/ER	11.54	16.43	38.98	10.94
Knee				
Add/Abd	29.74	8.40	5.17	50.00
Flex/Ext	1.84	3.45	55.65	11.94
IR/ER	14.15	33.3	71.59	40.15