The influence of music on movement speed in chronic pain

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STATEMENT OF ORIGINALITY

I attest to the fact that this thesis contains no material previously published or written by another person, except where references are made.

Elements of this Masters thesis provide original contributions to the understanding of the use of music to influence movement in a chronic pain population.

ACKNOWLEDGEMENTS

This study could not have been completed without the help of many people. I would like to express my sincere thanks and appreciation to my supervisor Dr. Maureen Simmonds for her guidance throughout the entire process. She made my journey through this Master's Program one of the richest and most memorable learning experiences in life. I learnt not only science, but also what one is capable of achieving in life. She has provided me with invaluable academic and non-academic advice. I sincerely appreciate the financial support provided by her.

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DEDICATION

This thesis is dedicated to my parents for their endless love, encouragement, support, guidance and unwavering belief in my desire to pursue higher education. To my dear sister Priya, for always being there for me. And to my dearest husband Sandeep, for being the best friend one can ever ask for. Thank you so much for always being there for me, for your endless love, guidance and support though this exciting journey. Thank you for being my mentor and helping me bounce ideas – scientific and otherwise with you. I cannot thank you all enough for your encouragement and belief in me that gave me the strength to pursue my dreams.

CONTRIBUTION OF AUTHORS

The work contained within this thesis is presented in a manuscript based format and consists of one paper that will be submitted for publication in a peer reviewed journal. This paper will be co-authored with Dr. Maureen Simmonds and Dr. Nancy Mayo. In accordance with the guidelines of the Faculty of Graduate and Postdoctoral Studies at McGill University, I would like to declare the contribution of all co-authors. The idea for the project was conceived by Dr. Simmonds. The experimental protocol was designed by all three individuals (Prasanna, Simmonds and Mayo). I was responsible for subject recruitment, data collection and data analyses. Dr. Mayo provided guidance in the data analyses. I was responsible for the preparation of the text and figures for the manuscript, receiving comments on drafts from both co-authors.

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ABSTRACT

Movement slowing among individuals with fibromyalgia (FM) adds to the burden of the condition. Music is known to influence movement speed in healthy individuals and it is plausible that it can be used to counteract slow movements in individuals with FM. Study objectives were to estimate a) whether walking to music of different tempi alters the gait speed in individuals with FM; b) whether music alters the mood, pain intensity, pain affect and perceived exertion in these individuals. A single subject research design was used. Eight women with FM walked under two different music conditions (fast and slow music) and a control (no music) condition. Outcome measures included gait speed, pain intensity, affect, mood and perceived exertion. Results showed that four subjects walked faster with fast music. No change was noted in the clinical measures. Music may be useful to improve gait speed in people with FM.

ABRÉGÉ

Le ralentissement du mouvement chez les personnes atteintes de fibromyalgie (FM) constitue un fardeau qui s'ajoute aux symptômes de cette maladie. Il est reconnu que la musique peut influencer la vitesse du mouvement chez les individus en bonne santé ; il est plausible qu'elle puisse aussi être utilisée pour contrecarrer le ralentissement des mouvements chez les individus atteints de FM. Les objectifs de cette étude consistaient à estimer a) si marcher en écoutant de la musique à différents tempi modifie la vitesse de marche chez les personnes atteintes de FM; b) si la musique modifie l'humeur, l'intensité de la douleur, l'émotion liée à la douleur et l'effort perçu par ces individus pendant leur marche. Une étude prospective à protocoles individuels (*single subject research design*) a été réalisée. Huit femmes atteintes de FM ont marché sous deux conditions musicalement différentes (musique lente ou rapide) et sous une condition contrôle (pas de musique). Les variables d'intérêts mesurées comprenaient la vitesse de marche, l'intensité de la douleur, l'émotion liée à la douleur, l'humeur et l'effort perçu. Les résultats ont montré que quatre sujets ont marché plus rapidement lorsqu'ils écoutaient la musique rapide. Aucun changement n'a été noté dans les mesures cliniques. Ces résultats indiquent que la musique pourrait être utilisée afin d'améliorer la vitesse de marche chez les personnes atteintes de FM.

CHAPTER 1 - INTRODUCTION

Chronic pain is defined as continuous or intermittent pain of at least six months duration. People with chronic pain tend to have generalized psychomotor slowing as also psychological distress including depression, pain related fear and the tendency to catastrophize (Sullivan, 2008). The movement slowing seen in these individuals is thought of initially to be a protective compensatory mechanism to help counter the original provoking problem. However, this movement dysfunction could persist due to cognitive, affective, behavioral as well as social factors (Simmonds, Moseley, & Vlaeyen, 2008). Slowing of movements tends to eventually be a contributor to the disability seen in these individuals (Smeets & Wittink, 2007). Slow movements are also physiologically inefficient and known to result in relatively high levels of energy expenditure (Rose, Morgan, & Gamble, 2006). Thus, for the same level of effort, people with pain are able to perform less work when compared to pain-free individuals (Simmonds, 2006).

There is a definite need to counter movement slowing in people with chronic pain. Treatment paradigms to achieve this include the use of speed targeted movements. This approach has been used previously in many patient groups for example stroke survivors (Lamontagne & Fung, 2004) and individuals with chronic pain (Wang, Harding, Simmonds, & Nicol, 2008). The change in movement speed may be induced with different techniques including the use of auditory cues such as music. It has been shown that music can influence movement and mood in healthy individuals (Karageorghis & Terry, 1997). Appropriate use of music has been shown to produce ergogenic effects such as reduced perceived exertion during exercise and to enhance the exercise experience in healthy individuals (Terry & Karageorghis, 2006). Thus, music can influence both physical and psychological domains.

The use of multi-dimensional treatment paradigms have been suggested in the management of chronic pain (Simmonds et al., 2008). The use of music may be a potential component of such a paradigm. Music is an inexpensive and easily available tool. In a review of studies looking at the effect of music on pain perception, Cepeda and colleagues (Cepeda, Carr, Lau, & Alvarez, 2006) concluded that music can help reduce pain perception. In the studies discussed in the review, individuals with chronic pain listened to music and did not participate in any physical activity. It is hence unknown whether music can alter pain and mood during physical activity and whether it contributes to improved physical performance.

Of the different components of music, the tempo or speed of music has been shown to be one of the main factors influencing a healthy individual's response to music during physical activity (Terry & Karageorghis, 2006). It would be interesting and potentially helpful if music of different tempos similarly influences movement performance in individuals with chronic pain. The use of music of different speeds may thus provide scope to understand the potential role of music in promoting speed targeted movements in chronic pain populations.

Fibromyalgia (FM) is a chronic pain condition characterized by generalized pain, movement difficulties, fatigue, mood disorders and cognitive dysfunction (Yunus, 2005). Music can influence movement and mood in healthy individuals and pain perception in individuals with chronic pain. Therefore, FM is an excellent condition to study the use of music to counter movement slowing. Furthermore, FM as a condition also provides scope to examine the effect of music on mood, pain intensity, affect and perceived exertion.

The purpose of this thesis is therefore:

i. to estimate whether walking to music of different tempos alters gait speed in individuals with FM.

ii. to estimate whether music can alter mood, pain intensity, affect and perceived exertion in these individuals.

The use of music to counter movement slowing in a chronic pain population is a relatively new area of research and hence this study has used a single subject design. The results of the study will provide original information on the potential for the use of music to improve walking speed in individuals with FM. These results may be used in future to help design studies to further examine the mechanisms, the effectiveness and potential clinical utility of music in rehabilitation.

This thesis is organized in a manuscript-based format, in accordance with the guidelines of the Faculty of Graduate and Postdoctoral Studies of McGill University. The main body of the thesis is split into six chapters. This first chapter has introduced the topic and the objectives of the thesis. Chapter 2 follows with a review of the literature relevant to the area of study. Chapter 3 gives a short discussion on the usefulness of single subject research designs in this area of study. Chapter 4 presents an original manuscript which examines the use of music to improve gait speed in individuals with fibromyalgia. Chapter 5 provides a summary and conclusion of the thesis and Chapter 6 details the references contained within the thesis.

CHAPTER 2 – REVIEW OF THE LITERATURE

2.1 Chronic Pain – The Problem

Chronic pain is a major health problem worldwide. It is defined as continuous or intermittent pain of at least six months duration. Most chronic pain is also recurrent. It is estimated that approximately 20% of the Canadian population suffer from persistent or chronic pain (Henry, 2008), (Moulin, Clark, Speechley, & Morley-Forster, 2002). A survey of 2012 individuals across Canada showed a higher prevalence for chronic pain among middle-aged women (Moulin et al., 2002). In this cohort, the mean duration of pain was 10.7 years and the average intensity of pain was 6.3 on a 10-point scale.

In addition to persistent pain, people with chronic pain may have psychomotor slowing and psychological distress which can include depression, pain related fear and the tendency to catastrophize (Sullivan, 2008). This associated physical and psychological dysfunction is known to have a formidable impact on the occupational health in these individuals. A recent study reported that neck pain accounted for 11% of the total absenteeism from work each year in Ontario alone (Cote et al., 2009). Similarly, in a study of people with fibromyalgia, 46.8% of persons reported a loss of job because of the overbearing nature of the disease (Al-Allaf, 2007). Chronic pain often places a huge economic burden on the patients as well as the health care system. In Canada, health care costs were estimated to be approximately three times greater for persons with chronic pain as compared to those without it (Lynch, Schopflocher, Taenzer, & Sinclair, 2009). Thus, the dysfunction associated with chronic pain is often more disabling than the pain itself and can contribute significantly to the high morbidity associated with chronic pain.

2.2 Psychomotor Slowing in Chronic Pain

Movement dysfunction contributes greatly to the disability seen in chronic pain (Lundberg, Styf, & Bullington, 2007). This difficulty in movement is predominant and pervasive, irrespective of the medical diagnosis of the patient. In other words, people with pain essentially move or slow down in a similar manner and the type of illness does not matter. Simmonds and colleagues tested a battery of physical performance measures in three different groups having pain – low back pain (Simmonds et al., 1998), cancer pain (Simmonds, 2002) and HIV/AIDS pain (Simmonds, Novy, & Sandoval, 2005). The results in these three studies were remarkably similar. Patients with pain had an overall decrease in their speed (in walking and performance of sit-to-stand tests) in comparison to age and sex matched healthy controls. Studies examining gait in fibromyalgia patients, reported a decrease in gait speed, stride length and cadence, in comparison to healthy controls (Auvinet, Bileckot, Alix, Chaleil, & Barrey, 2006), (Heredia Jimenez, Aparicio Garcia-Molina, Porres Foulquie, Delgado Fernandez, & Soto Hermoso, 2009).

The movement slowing may initially be a protective compensatory mechanism to help counter the original provoking problem. Indeed, slow movements help reduce the movement reaction forces (Cheng, Chen, Chen, & Lee, 1998), which is relevant in acute pain following injury to prevent further stress on the injured tissue. In addition, individuals may move more slowly due to the anticipated pain and fear of re-injury they believe are associated with movement and activity (Al-Obaidi, Al-Zoabi, Al-Shuwaie, Al-Zaabie, & Nelson, 2003). However, persistent slow movement during functional tasks renders them inefficient and may in turn contribute to the problem instead of resolving it (Simmonds, 2006).

In individuals with chronic pain, the slowing of movements may persist even though the original provoking problem may have been resolved. The underlying medical condition often does not provide an adequate explanation for this. This discrepancy in the biomedical understanding of pain has prompted study of pain from the biopsychosocial viewpoint (Engel, 1977). In the past decade, many models incorporating this perspective have been suggested, which help provide an insight into this behavioral change. A few important models are hence discussed.

According to the fear-avoidance model (Vlaeyen & Linton, 2000), a fearful association is made between painful movements and the pain itself. This fear is often more anticipated than real. The individual nevertheless attempts to persistently avoid the movements expected to cause pain. Over a period of time, these behavioral changes may just persist. It is interesting to note that this alteration continues even though reduction in pain has been achieved, thus contributing to disability (Crombez, Vlaeyen, Heuts, & Lysens, 1999).

The avoidance-endurance model (Hasenbring, 2000) accounts for the individual who continues to perform the painful activity/ movement in spite of persistent pain. According to this model, there are two types of endurance related responses. There are those individuals who suppress the thoughts of pain, have increased depression and high persistence behavior. In contrast, the second group has high persistence behavior but positive mood despite pain. Although, the exact mechanism by which endurance behavior leads to increased disability remains unclear (Karsdorp & Vlaeyen, 2009), a few hypotheses have been proposed. Persistence of a painful task may lead to physical overuse (Hasenbring, Hallner, & Rusu, 2009) and also cause the individual to be constantly exposed to the painful stimuli, which may over time increase pain perception (Karsdorp & Vlaeyen, 2009). These factors may eventually contribute to movement dysfunction.

In sum, there are cognitive, affective, behavioral as well social factors which may contribute to movement slowing in chronic pain individuals. Movement slowing and relative inactivity eventually leads to a deconditioning syndrome (Smeets & Wittink, 2007). Furthermore, slow movements are also physiologically inefficient. When the speed of walking is reduced in healthy individuals, the efficiency is reduced by almost 10% in comparison to walking at a comfortable speed (Rose et al., 2006). Thus, movement slowing due to chronic pain may result in relatively higher levels of energy expenditure. In other words, for the same level of effort, people with pain are able to perform less work when compared to pain-free individuals (Simmonds, 2006).

In addition to movement slowing, people with chronic pain may have associated impairments in cognitive functioning in part due to the attentional demands of the pain. A review on cognitive function in individuals with chronic pain concluded that there is altered attention capacity, processing speed and psychomotor speed in people with chronic pain (Hart, Martelli, & Zasler, 2000). Factors such as pain intensity (Eccleston & Crombez, 1999), tendency to catastrophize and pain related fear (Roth, Geisser, Theisen-Goodvich, & Dixon, 2005) may contribute to the cognitive disturbances. Pain is a primitive stimulus and demands attention. Individuals with pain therefore, may not be able to pay attention to other tasks because of this 'attentional black hole' (Eccleston & Crombez, 1999). Thus preoccupation with pain and pain related thoughts may play a role in the cognitive slowing in some of these individuals. Furthermore, depression which is commonly seen in people with chronic pain, is a known risk factor for cognitive slowing (Roth et al., 2005).

Thus, there is evidence for generalized psychomotor slowing in individuals with chronic pain. From the discussion above, it is interesting to note that similar factors seem to influence both movement as well as cognitive slowing. It therefore, seems intuitive that there is an association between movement and cognitive speed. In a recent study, people with chronic low back pain and healthy controls completed a battery of physical (timed tasks) and cognitive tasks (Wilson, Warner, & Simmonds, 2008). A weak to moderate correlation was found between the performances on physical tasks and those on the cognitive tests, especially those testing psychomotor speed.

It is clear that psychomotor slowing in chronic pain is not a result of pain alone; but many factors influence and modify this. It is a motor expression of a more comprehensive problem of which there are psychological, behavioral as well as social components. Hence a multi-method, multi-measure assessment and treatment model that deals with these aspects in an integrative manner is needed (Simmonds et al., 2008).

2.3 The Use of Speed Targeted Movements

Many different approaches are being used to counteract movement slowing in illness. One of them is the use of speed targeted movements. Speed training has been used in performance sports with excellent results (Paavolainen, Hakkinen, Hamalainen, Nummela, & Rusko, 1999). The basic principle in the use of this paradigm is task-specificity i.e. in order to perform a skill better, one should practice it (Carr & Shepherd, 1998). Therefore, to enable people with chronic pain walk faster and help counter movement slowing in them, they should be trained to walk faster. Hence, the use of speed targeted movements may hold potential to improve movement speed.

This principle has been used to counter movement slowing in different populations. Simmonds used a preferred brisk walking protocol in healthy elderly individuals (Simmonds, 2007). All subjects in the study were able to complete the protocol and also showed significant improvements in physical performance speed and endurance. This paradigm has also been used in stroke survivors (Pohl, Mehrholz, Ritschel, & Ruckriem, 2002; Lamontagne & Fung, 2004). In the study by Lamontagne and colleagues, individuals with stroke were asked to walk at their preferred or fast speeds while full weight bearing or with the help of body weight support. A combination of speed targeted movements and body weight support helped the individuals with stroke walk faster and also improved the kinematics and muscle activation patterns seen during walking (Lamontagne & Fung, 2004).

A recent study adapted this paradigm in individuals with chronic pain (Wang et al., 2008). The study looked at the use of a brisk walking protocol (BWP) namely the WINGATE protocol as an intervention. One group of patients received cognitive behavioral pain management program (C-BPMP) and the other received a combination of BWP and C-BPMP. The outcomes included physical and cognitive measures. Although the patients with chronic pain were able to complete the BWP, both groups showed similar improvement in physical performance measures which included walking speed and distance. However, the group receiving both BWP and C-BPMP showed improvements in the Stroop Test which is a test used to measure psychomotor speed. Thus, improvement in physical performance was accompanied by changes in the cognitive functioning. However, the BWP did not seem to have an additive effect in improving the physical parameters. This could be because the BWP was provided in addition to a cognitive behavioral program which had physical, cognitive and psychological elements. In essence, the use of speed targeted protocols to improve movement speed in individuals with chronic pain needs to studied further.

Different techniques may be used to induce speed training in individuals. These include (but are not limited to) the use of auditory cues. Auditory cues with the help of metronome have also been used to improve walking speed in various patient groups like stroke (Roerdink, Lamoth, Kwakkel, van Wieringen, & Beek, 2007) and Parkinson’s disease (Lim et al., 2005).

Similar to a metronome, music is composed of temporal arrangement of auditory tones and rhythms. Music is inexpensive, easily available and influences the attentional focus. It is also known to influence pain perception as also movement and mood in healthy individuals. People with chronic pain may have associated psychological issues such as anxiety and pain related fear. As discussed earlier, it is necessary to use multi-dimensional treatment paradigms in the management of chronic pain which influence physical as well as psychological domains. Hence, it becomes important to investigate the potential for the use of music to counter psychomotor slowing and improve movement and function in people with chronic pain and movement dysfunction.

2.4 Music in therapy

Music forms an important part of the lives of people. Primarily composed of auditory tones and rhythms; it has been used as a mode of expression and communication since ancient times. Music has always been acknowledged as an integral medium enriching any society, and is often an accompaniment to various art forms, sporting events or to solemnize religious ceremonies.

Although traditionally music has been perceived as an art form, its use as a healing medium has been recorded in history. A primary reason for this is perhaps its ability to facilitate breathing and help in relaxation (Livingston, 1979). Music is now being studied scientifically as a medium to aid therapy (Thaut, 2005). Newer insights suggest a promising use of music as a potential adjunct to therapy to reduce pain (Cepeda et al., 2006) and improve mood, movement and overall function (Karageorghis & Terry, 1997).

Components of Music

Terms such as tempo, rhythm, genre and mode describe the components of music. An understanding of these basic terms is necessary to critically appraise the literature in this area. The definitions of these terms are provided below (http://www.thefreedictionary.com accessed on April 5, 2009).

Tempo: Refers to the overall speed or pace of the piece.

Rhythm: Refers to the duration of a series of notes, and to the way that they group together into units.

Music style (or genre): It is a categorical and typological construct that identifies musical sounds as belonging to a particular category and type of music that can be distinguished from other types of music.

Mode: Any of the certain fixed arrangements of the diatonic tones of an octave, as the major and minor scales of Western music.

2.5 The influence of music on movement

Music has an intricate relationship with human body movement. While playing a musical instrument for example a drum, the rhythmic nature of the body movements helps produce music. Similarly, while listening to music the body also tends to move synchronously in response to musical stimuli. This phenomenon is called sensorimotor synchronization (Repp, 2006). This is commonly seen when soldiers walk to the beat of military marches. When people listen to a musical rhythm, they perceive a *beat* and a *metrical structure* in the rhythm that may enable coordination with the music. This phenomenon has been studied in tapping experiments. In these experiments, it was found that people tend to tap in synchrony to the auditory stimuli provided (Repp, 2005).

In another experiment (van Noorden & Moelants, 1999), it was found that people prefer to tap with a tempo that is close to a neutral tempo associated with natural body movements. This is called spontaneous tempo and is approximately 120 beats / min (bpm). This implies that when the auditory stimuli provided have a tempo of 120 bpm or its multiples, people tend to move with optimal levels of synchrony.

Music thus can be a potential instrument to influence the speed of movement. In a recent study (Styns, van Noorden, Moelants, & Leman, 2007), when healthy individuals walked while listening to musical fragments, it was observed that they showed a tendency to walk in synchrony to the music, while matching their cadence to the tempo of the music. The musical fragments were one-minute excerpts of songs from all genres of music. In the same study, people also walked to the beat of a metronome. It was found that people walked faster on music in comparison to a metronome with the same tempo. This is probably because, when people listen to a musical rhythm, they perceive a beat and a metrical structure in the rhythm, which facilitate coordination with the music (Large, 2000). Music has more number of events per beat thus giving a feeling of increased speed (McNeill, 1995), which may help people walk faster.

The appropriate music to be used, in order to maximally influence movement has been a topic of much discussion. Most authors agree that in order to facilitate better movement and increase exercise intensity, music that is motivational and uplifting should be used. A conceptual framework has been presented in order to facilitate the selection of music in sport and exercise (Terry & Karageorghis, 2006). According to this model, there are four factors that play a role in the motivational qualities of music-

i) *Rhythm Response* – The way people respond to the rhythm of the music being played, especially the tempo of the music.

ii) *Musicality* – Properties of the music like harmony and melody, which essentially depend on the pitch of the music.

iii) *Cultural Impact* – The extent to which music is a part of the social and cultural life of people.
iv) *Association* – The thoughts that a person may experience that are related to a certain incident that the listener is reminded of by the piece, but are completely unrelated to the music.

While listening to music, people respond primarily to the rhythmical elements of music (Karageorghis & Terry, 1997). Indeed, the rhythm in music is analogous to cyclical functions of the human body like gait and breathing. Hence, the rhythm response may be considered to be the most important factor while determining the qualities of music for exercise (Terry & Karageorghis, 2006).

It follows therefore that the tempo of the music needs to be considered when selecting music for exercise. Music is accepted as slow when the tempo is 60-80 bpm and fast when the tempo is 140-160 bpm (Karageorghis & Terry, 1997). A study that looked at the relation between exercise intensity and preferred tempo of music for exercise concluded that fast or medium tempo (120 bpm) music was preferred during low and moderate exercise intensities. In contrast, for high intensity exercises only fast tempo music was preferred (Karageorghis, Jones, & Low, 2006).

The manner in which music is played also impacts the performance of the task at hand (Terry & Karageorghis, 2006). When music is played in the background and the person does not consciously time his movements with the music, it is termed as asynchronous music. In contrast, in the case of synchronous music, the subject performs repetitive movements in time (sync) with the tempo of the music. In both these cases, the motivational quality of the music contributes to the person's response (Elliot, Carr & Savage, 2004; Karageorghis et al., 2009). Karageorghis and colleagues compared the effects of motivational and oudeterous (neutral) music of same tempo on synchronous activity in a recent study (Karageorghis et al., 2009). In this study, healthy individuals started walking on a treadmill at 75% HR max and continued till exhaustion. Motivational music helped increase the time to exhaustion and affect during the task. The subjects also reported lower levels of perceived exertion with motivational music when the intensity of exercise was lower. However, as the intensity of exercise reached levels of exhaustion, no difference was seen in this parameter between the two music conditions. This was attributed to the fact that the subjects may have paid more attention to walking in sync with the music at this high intensity of exercise and this could have overruled the motivational effects of the music. In other words, during the use of synchronous music in high intensity exercise, only the tempo of the music may be of value. However, further studies are needed in this area to determine if these findings are consistent.

2.6 The psychophysical effects of music

Significant benefits have been reported on provision of music during physical activity. These studies conducted on healthy university students have been summarized in table 2.1.

The activities used in the studies summarized are varied and range from submaximal to high work intensities. Fast and motivational music were preferred during exercise in the studies discussed above. The ergogenic effects in terms of improved performance and lower effort were greater with motivational music. Although, any music improved affect, a more consistent response was seen with the use of motivational music. Thus, exercising with appropriate music may produce ergogenic effects like improved motor performance, increased aerobic endurance and may also augment the exercise experience.

At the physiological level, listening to music during exercise can help lower the heart rate, systolic blood pressure, exercise lactate and norepinephrine production. These effects were noted in subjects running on treadmill at 70% VO2 max (Szmedra & Bacharach, 1998). However, when the exercise intensity reached maximal levels as in the case of a Wingate anaerobic test (Pujol & Langenfeld, 1999), these effects did not occur. At higher exercise intensities, the physiological compensations are likely to mask the effects of music, thus rendering it ineffective (Terry & Karageorghis, 2006).

2.7 The influence of music on mood

In the studies discussed in the above section, music improved affect during exercise. The reasons for this response could be multi-dimensional. Different factors including the structure of the music, personal preferences as also extra-musical associations may play a role in the emotional response.

Manipulations in the tempo and mode of the music have been shown to influence the mood of people. In a study by Dalla Bella and colleagues, healthy participants were presented with music excerpts which had been manipulated in tempo and mode (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001). The participants were asked to note the mood that the music piece evoked. It was found that faster tempi were associated with fear, anger and temper on one end of the spectrum, as also happiness and euphoria on the other. Slow tempi tended to evoke sadness. A similar trend was noted with major and minor modes, with major mode evoking happiness and minor mode evoking sorrow.

However, the influence of these components is not absolute. A key factor is the interaction between these components which may affect the level of enjoyment. For example, in the study by Husain et al. (Husain, Thompson, &

Schellenberg, 2002), four groups of healthy subjects were asked to listen to four different versions of the same melody. The versions varied in tempo and mode. Levels of arousal and mood were measured before and after listening to the music using the Profile of Mood States Test – Short Form. The arousal was found to be higher in the group listening to music in major mode with a faster tempo in comparison to the group listening to the music in minor mode with a slow tempo. It was also found that tempo manipulations primarily affected arousal while mode manipulations primarily affected mood. It therefore follows that music with a fast tempo and in major mode would more likely be suited for use in an exercise setting.

2.8 The influence of music on pain perception

In addition to its influence on movement and mood, music has been used to influence pain levels as well. Music has been used to alleviate pain and reduce anxiety in many different acute and chronic pain conditions (Cepeda et al., 2006). These include post-operative pain (Good et al., 1999), procedural pain (Bally, Campbell, Chesnick, & Tranmer, 2003), dental pain (Aitken, Wilson, Coury, & Moursi, 2002), chronic musculoskeletal pain (McCaffrey & Freeman, 2003) and cancer pain (Beck, 1991). A recent meta-analysis reported a moderate effect size for the use of music in relieving pain across conditions (Dileo, 2006).

The mechanisms involved in pain relief due to music seem multi-faceted. There are neurobiological and subjective dimensions to the effect of music on pain. Functional MRI (fMRI) studies have shown activity in subcortical structures including the ventral tegmental area, nucleus accumbens and the hypothalamus in individuals listening to music (Menon & Levitin, 2005). These structures form an important part of the dopaminergic pathway, the stimulation of which helps in pain modulation. Listening to music has also shown an increase in the release of serotonin (Evers & Suhr, 2000) and has enhanced the expression of μ opiate receptors (Stefano, Zhu, Cadet, Salamon, & Mantione, 2004). Serotonin plays a role in pain relief as well as enhancing the mood of the individual. Furthermore, music improves mood and helps reduce anxiety. It is an effective distractive measure, helping the individual to focus on the music rather than the pain. These factors help in reducing the subjective experience of pain.

In most studies, the type of music used varied from classical to popular. There is also considerable amount of variation in terms of whether the musical stimuli used were chosen by the patient or the researcher (Cepeda et al., 2006). While selecting music in an exercise setting for a pain population the use of pleasant music has been recommended (Roy, Peretz, & Rainville, 2008).

2.9 Fibromyalgia as a model for chronic pain study

As is evident from the discussion in the earlier sections, music may be an effective tool to influence movement, reduce pain and improve mood in a therapeutic setting. It therefore holds immense potential for use in a chronic pain population. Many chronic pain conditions including musculoskeletal pain, cancer pain and fibromyalgia (FM) have been used for implementing various strategies and interventions. FM is a central pain condition. Music has a central influence on movement, mood and pain, thus making FM an excellent condition in which the use of music can be studied and its potential as a tool in therapy and exercise can be evaluated.

FM is a chronic rheumatologic disorder characterized by generalized pain, fatigue, movement difficulties, mood disorders and cognitive dysfunction and pain on pressure, called tender points (Yunus, 2005). It is estimated that approximately five million people in the U.S. have a diagnosis of FM (Lawrence et al., 2008). A significantly higher rate of this condition is seen in women, with a female to male ratio of approximately 3:1. In Canada, it was estimated that persons with FM use more medications and outpatient health services in comparison to patients with other chronic pain conditions and at about twice the cost in comparison to the general population (White, Speechley, Harth, & Ostbye, 1999). Thus, the condition often places a major economic burden on the patients as well as the health care system.

The diagnosis of FM is made using The American College of Rheumatology (ACR) 1990 Criteria (Wolfe et al., 1990) which requires a) the presence of chronic widespread pain of≥ three months duration and b) at least 11 of 18 tender points on clinical examination. Although a standard method of diagnosis, it does not consider the other important symptoms of FM. Besides, most people with widespread generalized pain have tender points. Therefore, the use of these criteria for diagnosis of FM is now being challenged (Wolfe, 2003).

2.10 Fibromyalgia – The condition

People with FM are often hypervigilant to pain and have a greater tendency to report other somatic symptoms (Crombez, Eccleston, Van den Broeck, Goubert, & Van, 2004). They also experience sleep difficulties, irritable bowel syndrome, headaches as also affective symptoms like emotional distress, depression and decreased motivation (Yunus, 2005).

The widespread pain in FM has a pathophysiological basis, as discussed later, but it is also associated with psychosocial distress. Indeed, it has been suggested that FM pain is a medical label for psychosocial distress (Turk, 2004). According to Turk, the psychosocial distress of FM may be a consequence of having a pain problem or of having to prove one has a pain problem within the traditional medical system. Either way, the impact on psychological, physical and social function is potentially profound.

Regardless, such physical and psychological symptoms can contribute to high levels of disability (Verbunt, Pernot, & Smeets, 2008). Perceived symptoms and disability can impact the person's activities, abilities and self-esteem, which can in turn affect every dimension of life, including social roles, employment and leisure time (Mannerkorpi & Henriksson, 2007). This contributes toward a decreased level of health status and reduced quality of life (Hoffman & Dukes, 2008).

2.11 The pathophysiology of fibromyalgia

The pathophysiology of FM is complex and remains to be completely understood. However, many physiological and biochemical mechanisms are known to be involved.

Central sensitization may be a factor that contributes to the pathophysiology of FM (Yunus, 2008). It refers to the increased synaptic efficacy established in somatosensory neurons in the dorsal horn of the spinal cord following intense peripheral noxious stimuli, tissue injury or nerve damage (Ji, Kohno, Moore, & Woolf, 2003). This results in reduced pain thresholds, amplification of the pain response and a spread of pain sensitivity.

The neurobiological composition in FM is quite complex with alterations in the levels of 5-HT, norepinephrine, Substance P, amino acid neurotransmitters and cytokines, among others. The hypothalamic-pituitary axis is also involved in people with FM. All of these factors may contribute to altered central pain processing (Mease, 2005).

An altered dopaminergic pathway of nociception has also been noted in people with FM. A recent study by Wood and colleagues (Wood et al., 2007) showed that patients with FM had an abnormal dopamine response in the presence of a noxious stimulus. They also had a decreased activity of the enzyme dopa decarboxylase. This evidence suggests that alteration in the dopaminergic neurotransmission may also help to explain the primary clinical and affective symptoms of FM. However, what remains unclear is whether these changes (structural and neurophysiological) are a consequence of the chronic nociceptive input, or contribute to the pathogenesis of FM. In addition to the aforementioned mechanisms, psychological and behavioral factors like stress response may contribute to the maintenance of symptoms in some people with FM.

2.12 Altered Movement in Fibromyalgia

People with FM tend to move slowly across a range of functional tasks including walking, in comparison to their age and gender cohorts. People with FM who have lower health status, as measured by the Fibromyalgia Impact Questionnaire, show a greater tendency to walk slowly (Heredia Jimenez, Aparicio Garcia-Molina, Porres Foulquie, Delgado Fernandez, & Soto Hermoso, 2009). Beside a decrease in gait speed, studies have also shown reduced stride length and cadence in these individuals when compared to healthy controls (Auvinet, Bileckot, Alix, Chaleil, & Barrey, 2006), (Heredia Jimenez et al., 2009). Another study (Pierrynowski, 2005) showed that people with FM use different muscle recruitment patterns while walking when compared to healthy controls. During comfortable walking, people with FM preferentially use those muscles which are used by healthy individuals during fast walking. Hence, it is purported that this alteration may in turn contribute to the common complaint of fatigue during walking often reported by these individuals.

2.13 Management of Fibromyalgia

To date, best evidence practice in FM consists of a multidisciplinary approach. Non- pharmacological treatment includes physical and occupational therapy, exercise regimens, cognitive behavioral therapy and patient education with emphasis on self-management of symptoms. A combination of these approaches is being used to promote well-being in these patients. However, there is limited evidence for the effectiveness of these multidisciplinary approaches (Karjalainen et al., 2000). Therefore, there is a need to explore more treatment strategies in this population.

2.14 Rationale for the study

FM is a chronic pain condition which is associated with physical dysfunction as well as affective symptoms. It is feasible that music may impact mood and promote better movement. To date there is very little evidence on the impact of music on movement in a chronic pain population. It is also unclear whether music can alter pain and mood during physical activity, does it contribute to improved performance (Cepeda et al., 2006). Further, music is known to influence the speed of movement. Thus, the use of music with different tempi may provide scope to understand the potential role of music in promoting speed targeted movement. Beside, music is an inexpensive, safe and available intervention that patients can use themselves as part of self management. It would hence be of immense practical value to demonstrate that music is effective and it would also contribute to our understanding of mechanisms involved in the modulation of mood and movement.

Table 2.1 Summary of studies examining psychophysical effects of music

Authors	*Subjects, Type of Music Used*	*Experimental Activity*	*Outcome Variables*	*Results*
(Karageorghis, Jones, & Stuart, 2008)	n = 29, asynchronous music, 3 conditions - Mixed (fast & medium tempi), medium tempo – (115-120 bpm), fast (140-145 bpm)	Long duration (26 min) treadmill walking at 70% HR max	Music preference, intrinsic motivation, flow states	Medium tempo led to better flow states, increased preference and intrinsic motivation.
(Szabo, Small, & Leigh, 1999)	n = 24, asynchronous music, 5 conditions – no music, slow, fast, slow to fast (SFM) & fast to slow (FSM). In the last two conditions, music was changed when subject reached 70% HR max	Began cycling at 50 W, workload increased by 25 W/ min until exhaustion	Workload, HR, and post-experimental ratings of music condition preferences	Higher workload in SFM. No difference in HR between conditions. Fast and SFM conditions more preferred.
(Edworthy & Waring, 2006)	n = 30, asynchronous music, 5 conditions – no music, fast (200 bpm) & loud (80 dB; FL), fast & quiet (60 dB; FQ), slow (70 bpm) & loud (SL), slow & quiet (SQ)	10 min running trial on treadmill	Running speed, HR, perceived exertion and affect	Speed increased in FL and SQ conditions. HR increased in both fast conditions but greater in the FL condition. Positive affect in music conditions. No difference in perceived exertion between conditions.
(Elliott, Carr, & Savage,	n = 18, asynchronous music, 3 conditions – no music,	12 min trial on cycle ergometer, set at	Distance cycled and affect	Greater distance cycled during motivational music

2004)	motivational and neutral music	standardized perceived exertion		compared to no music. Higher affect in both music conditions compared to control.
(Karageorghis & Terry, 1999)	Asynchronous, motivational and neutral music	Submaximal treadmill running at 50% VO2 max	Perceived exertion, affect, HR, post-exercise mood	Positive affect, improved vigor (mood) and lower perceived exertion with motivational music.
(Karageorghis et al., 2009)	n = 30, synchronous music, 3 conditions – no music, motivational and neutral music	Treadmill walking, starting at 75% HR max and continuing till exhaustion	Time to exhaustion (endurance), perceived exertion, in-task affect, exs-induced mood	Greater endurance in music conditions (motivational > neutral). Higher affect with motivational music.

(HRmax – Heart Rate Maximum; W – Watts)

CHAPTER 3 – RATIONALE FOR THE USE OF SINGLE SUBJECT DESIGN

The use of music to counter movement slowing in a chronic pain population such as fibromyalgia (FM) is a relatively new area of study. There is evidence that the use of music influences movement in healthy individuals. But there is little information available on the effect of music on movement in people with chronic pain. Although, a good rationale for the use of music to influence movement in FM is present, the data required to design a traditional group based study is not available in the literature. Firstly, the association between music and gait speed in FM remains unclear. In such a case, an a priori assumption of the effect size has to be made to calculate the sample size. This however, may not be accurate. Beside, the strength of this association may be modified by many personal factors such as music preferences and also factors related to FM such as pain intensity, etc. A high level of variability in response is therefore, likely to be present among individuals. When data is analyzed at the group level, it averages out the variability. However, this variability can be very essential to help draw conclusions, especially when testing and generating hypotheses in a relatively new area of study. Hence in the study conducted as a part of this thesis, single subject research design (SSRD) was used instead of a traditional group based approach.

SSRD – An Overview

SSRD is basically an n of 1 study, where the individual is the unit of analyses. It has been used in rehabilitation research in many conditions such as cerebral palsy (Lilly & Powell, 1990), breast cancer (Keays, Harris, Lucyshyn & MacIntyre, 2008) among others. An important component of the SSRD is repeated systematic measurement of the outcome variable. This component has been considered in our study (refer chapter 4), wherein the study was designed to allow repeated measurement of gait speed across different music conditions. However, studies involving only a single individual have limited generalizability. In order to increase the generalizability and help identify common patterns of behavior, it has been recommended that in experiments using SSRD, the design needs to be replicated across a few subjects (Backman, Harris, Chisholm, &

Monette, 1997).

Data in SSRD is primarily analyzed using visual analyses. The main components of visual analyses are *level*, *trend* and *variability* analyses (Portney & Watkins, 2000). The *level* refers to the average of the outcome variable in each experimental condition and changes in the levels help identify the difference between conditions. The *trend* is used to indicate the direction of change of data points in each condition. Data is also examined for its stability and variability over repeated measurements. The descriptions of levels and trends are used to demonstrate the direction of data paths and do not indicate statistical significance.

However, visual inspection is a relatively subjective method of data analysis. Therefore, a combination of visual and statistical methods has been recommended for use in SSRD (Romeiser, Hickman, Harris & Heriza, 2008). While many different statistical approaches exist, the discussion here has been limited to the split middle technique (White, 1974), as this was used in our study.

In this technique generally, the regression line of the baseline is projected into intervention phase. The number of times the subject shows an improvement in the behavior as compared to the baseline is noted as successes. The total number of successes out of the total number trials in the intervention is counted. A binomial test of significance is then used to identify whether the intervention significantly changed the behavior as compared to baseline. However, in case of a strong baseline trend, the regression line will cross zero when taken to time infinity, therefore making this technique invalid. In a modification of the test (Patrick, Mozzoni, & Patrick, 2000), the end of the baseline trend is found and a straight horizontal line is fitted at the end of the baseline regression line, which is continued into the intervention phases. The primary assumption in such a case is that the end of the baseline trend represents the most stable state of the behavior under study.

SSRD when conducted with rigor can be a useful method to generate hypotheses in new areas of research. They help provide information that may be useful to guide design of future studies in the area.

CHAPTER 4 – MANUSCRIPT 1

The use of music to counter movement slowing in fibromyalgia – an exploratory study

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4.1 Abstract

People diagnosed with fibromyalgia (FM) are known to have widespread pain, fatigue, affective symptoms and psychomotor slowing. Research has demonstrated that music may influence movement, improve mood, decrease pain and reduce effort associated with exercise. Whether music can improve movement while reducing pain and improving mood in people with FM, is unknown. Hence, the purpose of this study was to examine the effects of music varied in tempo on gait speed and self-reported clinical measures in FM. An alternating treatment, single subject research design was used. Eight women with FM (mean age 50 ± 9.1 years) walked for three minutes in each of the three conditions - two music (fast, slow) and a no music control condition. Music was played using a MP3 player and subjects wore wireless headphones. The path for the walk test included the area covered by a GAITRite instrumented walkway. Outcome measures included gait speed measured on GAITRite and self-report of pain, mood and perceived exertion. Visual analyses of the data showed that average gait speed was higher with fast music and lower with slow music, as compared to baseline. Statistical analyses showed that four subjects walked faster with fast music. No change in the other clinical outcomes was noted across conditions in most subjects. The study provides preliminary evidence for the use of music especially that of fast tempo to improve gait speed in people with FM. Further research is necessary to demonstrate the clinical utility of music to improve movement in individuals with chronic pain.

Keywords: Fibromyalgia; Single subject design; Music; Gait;

4.2 Introduction

Fibromyalgia (FM) is a chronic rheumatologic disorder characterized by widespread musculoskeletal pain [21]. A significantly higher rate of this condition is seen in women, with a female to male ratio of approximately 3:1. In addition to persistent pain, individuals with FM may have movement slowing, sleep difficulties, irritable bowel syndrome, headaches and affective symptoms including emotional distress, depression and decreased motivation [42]. Individuals with FM tend to move slowly across a range of functional tasks including walking, in comparison to their age and gender cohorts. Slowing of movement may initially be a protective mechanism as slow movements help reduce the vertical reaction forces [11], which is relevant in acute pain following injury to prevent further stress on the injured tissue. In addition, individuals may move more slowly due to the anticipated pain and fear of re-injury they believe are associated with movement and activity [1]. However, these changes in movement may persist due to factors such as fear of movement [15] and catastrophic thinking [14]. In this way, the tendency to slow down may eventually contribute to the problem instead of resolving it [32].

Slow movements are physiologically inefficient and result in relatively high levels of energy expenditure. Thus for the same level of effort, people with pain are able to perform less work when compared to pain-free individuals [32]. Thus slow movements add to the burden of the health condition because everyday tasks take more time than usual. This altered speed in movements could eventually contribute to the disability seen in these individuals [37]. Studies examining movement, specifically gait in individuals with FM have reported a decrease in gait speed, stride length and cadence, in comparison to healthy controls [2], [16].

Thus, there is a definite need to address and counteract slowed movement in individuals with FM. Many different approaches including speed- targeted movements are being used to counteract movement slowing in illness [18]. Different techniques in this treatment paradigm include auditory and visual cues as also the use of brisk walking protocols like the WINGATE protocol [39] to modulate speed of movement. A combination of visual and auditory cues in a virtual environment is being used to improve gait speed in individuals with chronic pain [26]. Similarly, auditory cues with the help of metronome have been used to improve walking speed in various patient groups like stroke [29] and Parkinson's disease [20]. Similar to a metronome, music is composed of a temporal arrangement of auditory tones and rhythms. Therefore, auditory cues presented in the form of music could be explored to counteract movement slowing in chronic pain conditions including FM.

Music varied on tempo (defined as the speed of the music piece) has been used to influence movement speed in healthy individuals. Music is accepted as slow when the tempo is 60-80 beats per min (bpm) and fast when the tempo is 140-160 bpm [17]. In a study, where healthy people walked to music of different tempi, it was noted that they walked faster while listening to fast music [33]. This was primarily attributed to the phenomenon of sensorimotor synchronization whereby the body tends to move synchronously in response to the musical stimuli [28].

Music is known to have ergogenic effects as well. It has been shown to reduce the perception of effort while performing an activity in healthy individuals, thus making the individual perform more work with lower effort [17]. Music has also been used for pain relief in acute and chronic pain conditions [10]. It has been shown to improve mood [12] and reduce anxiety, thus reducing the subjective experience of pain. It serves as a distractive measure, allowing the individual to take his or her attention away from the pain and focus on the music instead.

Therefore, music may help target the problem of movement, - indeed psychomotor slowing, in an integrative manner, bringing about improvement in movement, while altering the pain and mood of the individual. However, the use of music in exercise has been tested only in healthy individuals [34]. To date there is little evidence on the impact of music on movement and physical performance in patient populations such as FM. It is also unknown whether music can alter pain and mood during physical activity in subjects with chronic pain and if so, does it contribute to improved performance and to what extent. Since music influences the speed of movement, the use of music with different tempi may provide scope to understand the potential role of music in promoting speed targeted movement. Furthermore, music is an inexpensive and available intervention that patients can use themselves as part of self management. It would therefore be of great practical value to demonstrate the use of music.

Hence, the objectives of the study were to estimate whether in individuals with FM walking to music of different tempos alters 1) gait speed; b) mood, pain intensity, affect and perceived exertion. We hypothesized that 1) individuals with FM would walk faster with music of any tempo when compared to their baseline speed; 2) music of any tempo would improve mood and reduce pain intensity, pain affect and perceived effort. Walking is a fundamental activity of daily living and hence was used in the study.

4.3 Methods

4.3.1 Study Design:

This study was designed as a multiple single subject design, specifically an alternating treatment design. Single subject design allows for hypothesis generation as data is analysed at the individual level [3].The association between music tempo and gait speed in a patients with FM remains unclear and may have a high level of variability. In most study designs, the data is analysed at the group level, thus averaging out the variability. However, this variability may be essential to help draw conclusions, especially when testing and generating hypotheses in a relatively new area of study.

4.3.2 Subjects:

Eight females aged 18-65 years, diagnosed with FM participated in the study. The demographic details of the subjects are summarized in table 4.1. The subjects were diagnosed with FM using the standard American College of Rheumatology (ACR) criteria of widespread pain and presence of 11 out of 18 defined tender points [41].

Insert table 4.1 here

Participants were included if they were able to – i) walk independently; ii) participate in physical activity and iii) comprehend and converse in either English and/or French. The exclusion criteria were - i) any condition precluding the ability to engage in physical activity (i.e. severe cardiac disease, dizziness, severe shortness of breath); ii) an additional diagnosis of systemic arthritis such as lupus or rheumatoid arthritis; iii) depression (score of >18 on the Beck Depression Inventory [4] and iv) hearing difficulties, use of a hearing aid or being uncomfortable with the use of headphones.

Ethical approval for this project was obtained from The Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR). Subjects were recruited from an outpatient department in a large urban rehabilitation centre. Potential interested participants were sent a letter describing the project and were asked to contact the study investigators if they were interested in participating. If the subjects met the criteria and agreed to participate, they were screened by a trained physiotherapist. Informed consent was then obtained from these participants before the study commenced.

4.3.3 Music Conditions:

Three levels of exposure i.e. two music conditions (fast and slow) and a no music control condition were presented in a random order in each of the three sessions.

Fast and slow music

Two pools of music pieces, differentiated on the basis of tempo, were presented to the subjects. The tempos were selected using the recommendation of 140-160 beats / min (bpm) for the fast condition and 60-80 bpm for the slow condition [17]. The pool of fast tempo music consisted of three tracks, each with a tempo of 140 bpm. Similarly, the pool of slow tempo music had three tracks with a tempo of 80 bpm. (Please refer to the list of music tracks in the appendix – A5) The duration of each of the tracks was edited to 3 minutes using Cool Edit Pro 2.1™ by Syntrillium Software.

At the beginning of the first session, the subjects listened to samples of all the tracks and were required to select one piece from each pool. The selected music pieces were then immediately recorded on a Creative 4GB Zen V Plus MP3 player and the same pieces were used for all three sessions. The music was played at a volume deemed comfortable by the participant using iLuv i903 Noise-Canceling Bluetooth Stereo Headphones. The headphones were cleaned with a sterile wrap after each subject.

Control Condition

No music was played for the same duration (i.e. 3 minutes) as the fast and slow music conditions. Subjects put on headphones in this condition as well, thus making it different from the baseline.

4.3.4 Outcome Variables:

Gait Speed: The primary outcome variable of gait speed was measured using the GAITRite instrumented walkway system.

Mood State: The current mood state was measured using the Profile of Mood States Test–Short Form (POMS-SF). POMS-SF consists of a list of 37 adjectives representing six dimensions of affect or mood, including tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. Subjects are required to rate the adjectives on a 5-point intensity scale, in terms of how they are feeling right now (0=not at all and 4=extremely). Except for vigor-activity domain (which is weighed negatively), the other dimensions/domains are weighted/scored positively. A higher score indicates greater mood disturbance/more distress. POMS-SF has very good reliability (correlation coefficient i.e. $r = 0.9$) and validity [31].

Pain Intensity and Affect: Pain intensity and affect were measured using Visual Analogue Scales (VAS). Pain affect is a measure of the unpleasantness experienced because of the pain. Ten cm. scales were used to measure both. End points on the scale were marked 'no pain' and 'worst possible pain' to measure intensity, whereas for the scale to measure affect, the endpoints were 'not unpleasant' to 'extremely unpleasant'. The stability of the VAS score is excellent with $r = 0.9$ [27].

Perceived Exertion: The rate of perceived exertion after each experimental condition was measured using the Modified Borg's Scale. It is a standardized self-administered scale of 10 points, with 0 indicating 'none at all' and 10 indicating 'very, very strong'. It has been shown to be a reliable (ICC > 0.98) [23] and valid measure of physical exertion [8].

4.3.5 Explanatory Variable:

Health Status: The current health status of the individuals with FM was measured using The Fibromyalgia Impact Questionnaire (FIQ). It is a brief ten-item, self-administered instrument. It measures physical functioning, work status; depression, anxiety, sleep, pain, stiffness, fatigue and well-being in patients with FM. Subscales of the FIQ are normalized so that each subscale generates a maximum score of 10. Higher scores indicate greater impairment [9]. FIQ has been shown to have good reliability and validity [5] and minimally clinically important difference (MCID) of 14 points [6].

4.3.6 Equipment:

The GAITRite Instrumented Walkway: GAITRite is a system that measures the temporal and spatial characteristics of gait including velocity, cadence, stride length, stance time, etc. It consists of a 14 feet long walkway with a series of embedded force transducers and 6 sensor pads enclosed in a roll-up carpet. The active area is a grid of 24 inches * 144 inches, with a total of 13824 sensors. As the subject walks across the GAITRite, the geometry and relative arrangement of each footfall (as a function of time) is recorded by the system. The software then processes the raw data into footfall patterns and computes the temporal and spatial parameters in real time (GAITRite website). The reliability of GAITRite for the measurement of walking speed, cadence and step length is excellent with ICC values ranging from 0.82-0.92 [22]. It has very good concurrent validity of r = 0.99 for the above parameters with the Clinical Stride Analyzer [7].

4.3.7 Procedure:

The study was conducted at the Pain, Mind and Movement Laboratory at the Constance Lethbridge Rehabilitation Centre, Montreal. Subjects were required to come to the lab on three days (one day/ week) in three consecutive weeks. Data collection over three sessions allowed for repeated systematic measurement of the outcome variables, which is a key component of SSRD.

Insert table 4.2 here

At the beginning of the study, the subjects' demographics and information related to formal training in music, presence of co-morbid factors and the use of medications were obtained. Subjects completed the FIQ and rated their current level of physical activity with a question – 'How often in the past 4 weeks have you participated in any form of exercise?' A six point Likert scale ranging from 1-6 (1= never and 6= always) was provided to assess the response.

At the beginning of each session, the subjects were instructed to walk for three minutes and baseline data was obtained. The path of the walk test (25.6 m long) was predetermined along the periphery of the lab and included the area covered by the GAITRite. This indicated that subjects continued to walk on the path for three minutes with data being collected each time they walked over the GAITRite.

Subjects then walked (on the predetermined path) under two music conditions (fast and slow) and a control no music condition. These were presented in a counterbalanced order. Each music condition lasted for a duration of three minutes. The

MP3 player with the selected tracks was placed in a pouch clipped to the subjects and the headphones were put on and adjusted for comfort and volume level. Subjects were instructed to *'walk at their normal pace'* at all times during the study. While performing the test, the subjects were given the option to rest if required. However, none of the subjects indicated the need for a break.

The subjects completed POMS-SF, VAS (pain intensity and affect) and Borg's Scale after each test condition including the baseline. They also rated the extent to which they liked the music using a 6-point Likert Scale (1= strongly disliked to 6= strongly liked). A rest period of 10 minutes at the least was provided between conditions.

A short debriefing session was conducted with the subjects after the completion of all the three sessions. This helped gain an insight into the experiences the subjects had while walking with the music in the study. Subjects were asked what they felt about the study and also describe their previous experiences with music and dance. A complete list of the debriefing questions used is available in Appendix A6.

4.3.8 Data analysis

Since the study was designed as a single subject research design (SSRD), the objective of the data analysis procedures was to estimate if the exposure variable had an effect on the outcome variables in each individual subject. The data was analyzed using visual analysis. Visual inspection is somewhat subjective [13] and hence, it was combined with statistical analysis using the split middle technique [40].

In visual analysis, the graphed data for the primary outcome of gait speed was analyzed for changes in the levels, trends and variability within and across conditions [25]. The level refers to the average gait speed in each condition and change in the levels was used to identify the difference between conditions. The trend was used to indicate the direction of change in each condition and was also examined for its stability. The descriptions of levels and trends are used to demonstrate the direction of data paths and do not indicate statistical significance.

In the split middle technique, the regression line of the baseline data points is projected into the intervention phase. The number of data points in the intervention phase that are above the projected line is noted and a binomial test of significance is used. However, in case of a strong baseline trend, the regression line will cross zero when taken to time infinity, therefore making this technique invalid. In a modification of the test [24], the end of the baseline trend is found and a horizontal line is fitted at the end of the baseline regression line, which is continued into the intervention phases. The primary assumption in such a case is that the end of the baseline trend represents the most stable state of the behavior under study. However, this was not the case with the data points in this study. Therefore, the median of the baseline data points was used to determine the baseline trend, which was then extended horizontally into the intervention phases. The level of significance of the binomial test was set at $p < 0.05$.

The secondary outcome variables of pain intensity, pain affect, mood and effort were not analyzed graphically due to the lack of sufficient (>3) number of data points in each condition every session. However, these variables were evaluated for change across conditions using the minimal detectable change values available for these measures.

4.4 Results

Eight women with FM participated in the study. The average age of the subjects was 50 ± 9.1 years and their average FIQ scores were 62 ± 10.8. The demographic information of the subjects has been summarized in table 4.1.

4.4.1 Gait Speed

Since subjects were instructed to *'walk at their normal pace'* during the study and each experimental condition lasted for a period of three minutes, a variable number of trials was noted for subjects across conditions. A trial is operationally defined as the event when a subject walks over the GAITRite. The value of gait speed obtained is the average speed of the total number of steps walked over the GAITRite mat in every trial.

Visual Analysis

Fast Music Condition

In general, average gait speed in the fast music condition was higher than the baseline in most subjects. When gait speeds in the fast condition for all subjects were considered, 13 out of 24 comparisons showed improved levels as compared to baseline. In the graphs (Figs. 4.1 – 4.8) showing the gait speed across conditions, when compared to baseline a higher level was noted for one subject (B) across all sessions; three subjects (A, E and G) in two sessions and four subjects (C, D, F and H) in at least one session. A lower level in gait speed was noted for two subjects (F and H) in two sessions and four subjects (C, D, E and G) in one session. No change in level was observed for three subjects (A, C, D) in one session.

Insert figures 4.1 to 4.8 here

Improving trends in gait speed were seen in two sessions of one subject (E). A decelerating trend was noted for three subjects (A, C and H) across all sessions; two subjects (F and G) in two sessions and three subjects (B, D, and E) in one session. A stable trend was observed for two subjects (B and D) in two sessions and two subjects (F and G) in one session.

Slow Music Condition

In general, average gait speed in the slow music condition of most subjects was lower than the baseline. When gait speeds in the slow condition for all subjects were considered, 16 out of 24 comparisons showed lower levels as compared to baseline. In the graphs (Figs. 4.1 – 4.8) showing the gait speed across conditions, when compared to baseline a lower level was observed for two subjects (D and G) across all sessions; four subjects (A, C, E and H) in two sessions and two subjects (B and F) in one session. A higher level in gait speed was noted for one subject (B) in two sessions and four subjects

(A, C, E and F) in one session. No change in level was noted for two subjects (F and H) in one session.

Decelerating trends in gait speed were noted for two subjects (A and C) across all sessions; two subjects (F and H) in two sessions and two subjects (D and E) in one session. An accelerating trend was noted for three subjects (B, E and G) in two sessions and one subject (D) in one session. A stable trend was observed for five subjects (B, D, F, G and H) in one session.

No Music Condition

A mixed response was seen with the average gait speed higher than the baseline in some subjects and lower in the others. In the graphs (Figs. 4.1 – 4.8) showing the gait speed across conditions, when compared to baseline a higher level in gait speed was noted for one subject (B) across all sessions; three subjects (D, F and H) in two sessions and two subjects (A and E) in one session. A lower level was noted for one subject (G) across all sessions; three subjects (A, C and E) in two sessions and three subjects (D, F and H) in one session. No change in level was noted for one subject (C) in one session.

Decelerating trends in gait speed were observed for two subjects (B and C) across all sessions; three subjects (A, D and G) in two sessions and three subjects (E, F and H) in one session. Accelerating trends were seen for three subjects (D, F and H) in one session. A stable trend was noted for one subject (E) in two sessions and four subjects (A, F, G and H) in one session.

Statistical Analysis

The binomial test results indicated that one subject (B) walked faster in the fast music condition in all sessions as compared to baseline (refer table 4.3). Three subjects (E, F and G) walked faster in the fast condition in two sessions, while four subjects (A, C, D and H) walked faster in only one session. In the slow condition, one subject (G) walked slower in all sessions as compared to baseline. Two subjects (D and E) walked slower in two sessions while four subjects (A, B, C and H) walked slower in one session. Two subjects (B and F) walked faster in the slow music condition in two sessions. In the no music condition, one subject (G) walked slower in all sessions as compared to baseline. Six subjects (A, C, D, E, F and H) walked slower in one session. Four subjects (B, D, F and H) walked faster in two of the no music conditions.

The gait speed data was also examined to see if the order of presentation of music conditions affected the response of the subjects. Order effect was not found to be present.

Insert table 3.3 here

4.4.2 Mood State

Overall mood state was generally stable across conditions. The mood state in the fast condition remained the same for most subjects, except for two subjects (D and E) in whom the mood was improved compared to baseline. In the slow music and the no music condition, the mood state remained the same for all subjects.

Insert table 4.4 here

4.4.3 Pain Intensity

The pain intensity in the fast condition remained the same for most subjects, except for three subjects (D, E and F) in whom the pain intensity was lower as compared to baseline (refer table 4.5). Similarly in the slow music condition, the pain intensity remained the same for most subjects except for three subjects (D, E and G) in whom pain intensity was reduced. The pain intensity increased in the fast and slow condition for one subject (C). In the no music condition, the pain intensity remained the same for most subjects except for three subjects (D, F and G) in whom the pain intensity reduced.

Insert table 4.5 here

4.4.4 Pain Affect

The pain affect in the fast condition remained the same for most subjects, except for two subjects (D and E) in whom the pain affect was lower as compared to baseline (table 4.6). Similarly in the slow music condition, the pain affect remained the same for most subjects except for three subjects (D, E and G) in whom the pain affect reduced. In the no music condition, the pain affect remained the same for most subjects except for one subject (D) in whom the pain affect reduced.

Insert table 4.6 here

4.4.5 Perceived Effort

The perceived effort in the fast condition remained the same for most subjects, except for two subjects (D and H) in whom the effort was higher as compared to baseline (table 4.7). Similarly in the slow and no music conditions, the effort remained the same for most subjects except for subjects D and E in whom the effort was higher in slow and no music conditions respectively.

Insert table 4.7 here

4.5 Discussion

The current study was designed to explore the use of music to counter movement slowing in FM. Walking is a fundamental activity. It is a component of many physical performance measures because the improvement in parameters of walking may generalize to other tasks and functions. Hence, the study was designed to examine whether gait speed in individuals with FM could be altered using music of different tempos. It also looked at the effect of music on pain intensity, pain affect, mood and effort.

It was hypothesized that subjects would walk faster with music of any tempo when compared to their baseline. In the fast music condition, all subjects walked faster in at least one session; three subjects walked faster in two sessions and one subject walked fast across all sessions. In the slow music condition, three out of the eight subjects walked faster in at least one session and a further two subjects walked faster than baseline in two out of the three sessions. With no music, a mixed response was seen.

The findings in our study are similar to those found in healthy individuals [33]. In the study by Styns and colleagues, when healthy individuals walked while listening to music of different tempi, maximum walking speed was noted when the tempo of music was between 126 to 142 bpm. The music used in the fast condition in our study was in this range (140 bpm) and there was a greater tendency for people to walk faster with this music condition. In the study by Styns et al., people were explicitly asked to synchronize their walking with the music being played. This was not the case in our study, where no such instructions were provided. However, subjects still walked faster with fast music and some walked faster with slow music as well. Furthermore, subjects were instructed to walk at their 'comfortable speed'. It would be therefore interesting to consider whether a different set of instructions would have influenced the results.

The most likely primary reason for the increase in gait speed in our study participants was the fact that music allowed for the phenomenon of rhythmic synchronization in these individuals. In other words, it may have provided a temporal cue to assist walking. According to Thaut, the temporal arrangement of sound in music could be considered analogous to the synchronous signals emitted by the central nervous system, which are responsible for movement production. Therefore, music may be a potent stimulus to ensure sensorimotor synchronization [35]. There is also evidence that rhythmic sound cues can alter the arousal state of spinal motor neurons, thus reducing the threshold for movement to occur. This is known to help counteract bradykinesia [36].

Additionally, music also seems to have helped the subjects divert their attention away from the painful stimuli and focus on the music. In the debriefing session conducted after the study, one subject (B) reported that walking to music made her forget the fact that she walked with a limp. Personal factors like musical preference and previous experience with the use of music may also have contributed to the response. The four subjects (B, E, F and G) who responded to fast music in more than one session reported that they enjoyed the music used in the study. One of the subjects (B) had previously used music while walking on a few occasions. While all these four subjects liked dancing, two of these subjects (B and E) had danced before at a professional level.

A variable response was seen in four subjects (A, C, D and H) as they walked faster with fast music in only one session. This may be attributed to many factors. One subject (A) reported high pre-test pain levels across all sessions as compared to other subjects in the study and also complained of pain, stiffness and fatigue while participating in the study. An increase in the mean pain intensity was noted for one subject (C) in the fast condition across all sessions. This subject (C) also reported difficulty especially during the third session due to fatigue. Two subjects (D and H) reported higher perceived effort during the fast condition. One subject (H) reported that she did not find the study interesting and complained of occasional dizziness while performing the task.

It is interesting to note that all subjects bar one (H), reported that they felt they walked faster with the music and that 'following the beat of the music' while walking helped them. Three subjects (A, C and D) perceived that they performed better even though their gait speed did not increase significantly. Thus these subjects' perception of their performance did not seem to be accurate. These findings are similar to those seen in a study in which stroke patients over-estimated their ability to perform activities of self-care [30]. Lee and colleagues have suggested that patients' self-report of activity may be influenced by psychosocial factors like expectancies of pain and reinjury, psychological distress levels as also motivation and self-efficacy levels [19]. Similar factors may have influenced the subjects in our study, especially since music is known to reduce anxiety and may increase motivation. Music may have contributed to reducing expectancies of pain and reinjury. Furthermore, subjects in an experimental setting are known to provide socially acceptable responses and this was perhaps the case here. These findings thus indicate the need to complement the use of self-report measures with physical performance tests.

A mixed response was noted in the no music condition, wherein some subjects walked faster and the others slower as compared to baseline. This was an expected result because the subjects did not have any external cues or distraction in this condition.

A decelerating trend in the speed responses was seen across conditions in most subjects. This may be accounted for by fatigue experienced by the subjects during the activity. A study by Pierrynowski and colleagues showed that during comfortable walking, people with FM preferentially use those muscles which are used by healthy individuals during fast walking. This altered muscle recruitment pattern may have contributed to fatigue in the study subjects.

However, subjects did not report an increase in perceived exertion during the activity. The Borg's Scale which was used in this study measures perceived effort and not actual effort. It is therefore plausible that subjects' perception of their performance may have been inaccurate. Furthermore, music is known to have psychophysical effects which reduce the perception of effort during the performance of an activity [34]. Therefore, the finding that despite the presence of decelerating trends, subjects reported less perceived effort supports our hypothesis that music may be useful in reducing perceived exertion in these individuals.

In all subjects bar one, clinical variables of pain intensity, pain affect and mood remained the same across conditions. In one subject (E), increase in gait speed during fast music was accompanied by lowered pain intensity, pain affect and improved mood. Thus, subjects walked faster, in at least one session without an increase in pain intensity and effort. Subjects were asked to rate their pain intensity levels immediately after the walk test in each condition. Although, music may have helped divert the subjects' attention away from pain during the walk tests, the immediate self-report of pain could have once again drawn attention to the pain state. Indeed, such reactive effects of pain measurement have been noted with the use of self-report measures such as the VAS [38]. It is therefore plausible that these effects could have contributed to the results seen in this study.

Mood scores as measured by the POMS-SF remained the same across conditions for all subjects. It is probable that the duration of the experimental condition i.e. three minutes may have been insufficient to bring about changes in mood. It would perhaps be interesting to conduct experiments of a longer duration in future to elicit the effects of music. However, most subjects reported a subjective feeling of reduced anxiety while walking with music in the study, though this was not reflected in the clinical scale.

The debriefing session conducted after the completion of the study provided invaluable insights into the experiences of the subjects with music in the study and helped explain the results obtained. It is beyond the scope of this study to detail the subjective experiences reported by the subjects. However, some of these comments are worthy of note. With one exception, all subjects indicated that they enjoyed the study. Beside general comments about the study, many subjects made interesting observations about the way music affected them. Most notably, one subject (B) reported that she felt she could pay more attention to her posture while walking to music. Another subject (F) felt that the music improved her movement and indicated that she would like to use music in the future while exercising.

One of the subjects (H) reported that music helped her perform repetitive activities (such as typing, weaving, etc.) better. She also reported that she used only specific type of music during these activities which helped her synchronize her movements. It is interesting to note that this subject (H) did not respond to the music used in the study. It is possible that this subject learnt to use music to synchronize her movements in a particular context, but was unable to transfer this to another context like walking. However it is just as plausible that her beliefs and perceptions were not accurate.

4.6 Limitations of the Study

Although single subject research design limits the generalizability of the findings, this design was useful to examine the variability in responses. This variance often seen in patient populations such as FM may average out with the use of group based designs. Thus the results may indicate no effect of the intervention, while in reality this may not be true. Hence this design was used. Another limitation of the study was that there was less choice in the number of tracks and the genre of music used in the study. All tracks used belonged to the popular genre of music. Although most subjects enjoyed the music played, they felt the need for greater choice in music and more variety in the type of music used.

4.7 Conclusion

Movement slowing is an important problem in FM because it adds a time burden to the general health condition and relatively increases the energy expenditure, thus making people with FM perform less work for more effort. Appropriate treatment interventions are hence necessary to address this issue. This study provided preliminary evidence for the use of music especially that of fast tempo to improve gait speed in people with FM. It also showed that music may be a potential tool for individuals with chronic pain to perform better without increasing their pain levels. Pain intensity, fatigue, fitness levels, music preferences and prior experiences with music were identified as factors that could have contributed to the effects seen in these individuals. However, the extent to which these variables influence the effects of music is currently unknown and can be the focus of future research. Studies with larger samples are hence necessary to further validate these results to demonstrate the effectiveness and potential clinical utility of music in rehabilitation. This knowledge will be very helpful since the use of music in therapy is cost-effective and hence can be easily transferred to the clinical settings.

Acknowledgements
This research was supported by grants from Canadian Foundation of Innovation.

4.8 Tables and figures

Table 4.1: Demographic details of the subjects

Subject	*Age*	*Music Training*	*Frequency of exs/wk*	*FIQ Scores*
A	46	None	Low	72.1 (2.1)
B	52	None	Moderate	66.4 (8.9)
C	50	Basic	Low	51.4 (12.7)
D	63	Basic	Low	69.6 (3.2)
E	32	Professional	Low	65.7 (24.5)
F	58	None	High	56.2 (12.1)
G	49	None	Moderate	70.5 (4.6)
H	52	Basic	Moderate	41.7 (5.7)

FIQ: Fibromyalgia Impact Questionnaire. The total FIQ score is out of 100. A lower score indicates better health status. Means and standard deviations of FIQ scores are presented.

Table 4.2: Summary of the study procedure

Pre – Test Period (week 1)	*Baseline (week 1,2 & 3)*	*Testing Period (week 1, 2 & 3)*		
		*Music Condition A**	*Music Condition B**	*Music Condition C**
Explanation of the study Completion of demographic details and FIQ.	1. Completion of VAS, POMS-SF 2. Testing on the GAITRite for 3 minutes. 3. Completion of Borg's Scale, VAS and POMS –SF 4. Rest for ~10 minutes	1. Testing on GAITRite for 3 minutes. 2. Outcome measures. 3. Rest for ~10 minutes	1. Testing on GAITRite for 3 minutes. 2. Outcome measures. 3. Rest for ~10 minutes	1. Testing on GAITRite for 3 minutes. 2. Outcome measures. 3. Rest for ~10 minutes. 4. Debriefing session (after 3rd week only).

FIQ: Fibromyalgia Impact Questionnaire; VAS: Visual Analogue Scale; POMS-SF: Profile of Moods State – Short Form; Condition A: Fast Music; Condition B: Slow Music; Condition C: No Music. *The conditions were presented in a random order every week.

Table 4.3: Summary of the analysis of gait speed using the binomial test for all subjects

Participant & Session	*Number of Successes*			*Probability using binomial test*		
	Fast	*Slow*	*No Music*	*Fast*	*Slow*	*No Music*
A1	3/5	1/4	0/5	0.31	0.25	*0.03* *
A2	5/5	4/5	4/5	**0.03***	0.16	0.16
A3	3/6	0/5	2/6	0.31	*0.03* *	0.23
B1	8/8	0/7	4/6	**0.00***	*0.01* *	0.23
B2	8/8	7/7	8/8	**0.00***	**0.01***	**0.00***
B3	7/7	8/8	7/7	**0.01***	**0.00***	**0.01***
C1	**7/7**	5/7	5/7	**0.01***	0.16	0.16
C2	2/7	0/7	2/7	0.16	*0.01* *	0.16
C3	2/7	2/7	0/6	0.16	0.16	*0.02* *
D1	4/9	3/8	8/9	0.25	0.22	**0.02***
D2	6/7	0/6	6/7	**0.05***	*0.02* *	**0.05***
D3	1/6	0/6	0/6	0.09	*0.02* *	*0.02* *
E1	3/7	0/7	1/7	0.27	*0.01* *	*0.05* *
E2	8/8	**7/7**	2/7	**0.00***	**0.01***	0.16
E3	8/9	0/8	8/9	**0.02***	*0.00* *	**0.02***
F1	2/9	5/12	2/11	0.07+	0.19	*0.03* *
F2	10/10	11/11	8/10	**0.00***	**0.00***	**0.04***
F3	7/11	10/12	12/12	0.16	**0.02***	**0.00***
G1	7/8	0/6	0/7	**0.03***	*0.02* *	*0.01* *
G2	0/7	*0/6*	*0/8*	*0.01* *	*0.02* *	*0.00* *
G3	9/9	0/8	0/7	**0.00***	*0.00* *	*0.01* *
H1	1/6	2/6	0/6	0.09	0.23	*0.02* *
H2	6/7	1/6	6/6	**0.05***	0.09	**0.02***
H3	1/6	0/6	7/7	0.09	*0.02* *	**0.01***

[* Statistically significant value ($p < 0.05$); + Strong trend toward statistical significance]. Values in bold indicate that the subject's gait speed increased. Values in italics indicate that the subject's gait speed reduced.

The number of successes indicates the number of times the subjects' gait speed in the respective condition is greater than the median of baseline. Note: The number of trials for each subject in each condition was different because the subject was asked to walk for a fixed duration of time and was not expected to complete a specific number of trials in each condition.

Table 4.4: Means and standard deviations of mood scores on POMS-SF for all subjects

Subject	*Baseline*	*Fast*	*Slow*	*No Music*
A	13.3 (2.9)	14.2 (0.6)	13.6 (1.2)	14.1 (0.7)
B	6.8 (2.6)	6.9 (2.1)	7.1 (2.9)	7.5 (2.9)
C	3.7 (0.4)	4.5 (0.5)	4.4 (0.2)	4.3 (0.4)
D	6.4 (1.8)	**4.1** (0.4)	4.8 (0.9)	4.8 (1.1)
E	6.1 (1.5)	**3.4** (0.6)	4.5 (0.6)	6.2 (1.8)
F	4.2 (1)	4.1 (1.1)	3.8 (1.8)	3.6 (1.7)
G	6.6 (1.6)	6.2 (0.7)	6 (0.6)	6.4 (1)
H	6 (0.4)	6.4 (0.4)	6.4 (0.2)	6.2 (0.2)

Values in bold indicate that the subject's mood showed a positive change.

The total score on the POMS-SF ranges from 0-24 with a lower score indicating a positive mood.

Table 4.5: Means and standard deviations of pain intensity scores on VAS for all subjects

Subject	*Baseline*	*Fast*	*Slow*	*No Music*
A	8.6 (0.5)	8.5 (0.3)	8.6 (0.1)	8.8 (0.3)
B	5 (0.3)	4.6 (0.5)	4.5 (0.2)	4.4 (0.5)
C	1 (0.1)	*2.1* (0.5)	*2.4* (0.3)	2 (0.7)
D	5.7 (0.9)	**3.6** (0.7)	**3.8** (1.3)	**4.2** (0.9)
E	6.1 (3.7)	**3.5** (2.8)	**2.8** (2.6)	5.8 (4.4)
F	5.3 (2.3)	**4.3** (2.4)	4.4 (2.5)	**3.8** (2)
G	6.3 (2.3)	5.4 (2.4)	**4.9** (2.4)	**5.2** (2)
H	4.4 (0.7)	4.8 (1.4)	5 (0.8)	4.8 (0.6)

Values in bold indicate that the subject's pain intensity was lower than baseline. Values in italics indicate that the subject's pain intensity was higher than baseline.

The score on the VAS ranges from 0-10 with a lower score indicating lower pain intensity.

Table 4.6: Means and standard deviations of pain affect scores on VAS for all subjects

Subject	*Baseline*	*Fast*	*Slow*	*No Music*
A	8.5 (0.6)	8.6 (0.7)	8.2 (0.5)	8.7 (0.5)
B	5.2 (0.1)	5.1 (0.8)	5 (0.4)	5.8 (1.3)
C	2.7 (1)	2.6 (0.7)	2.9 (1.2)	2.7 (1.1)
D	5.6 (1.2)	**3** (0.3)	**3.7** (1.1)	**4.1** (0.6)
E	3.1 (2)	**1.5** (1.7)	**1.9** (1.5)	2.9 (2.2)
F	2.4 (2.6)	2.8 (2.7)	2.4 (1.5)	2.4 (3.7)
G	6.1 (2.6)	6.5 (1.9)	**4.8** (2.6)	6.5 (1.7)
H	4 (1.4)	4.7 (1)	4.9 (0.5)	4.5 (1)

Values in bold indicate that the subject's pain affect was lower than baseline.

The score on the VAS ranges from 0-10 with a lower score indicating lower pain affect.

Table 4.7: Means and standard deviations of scores of perceived exertion on Modified Borg's Scale for all subjects

Subject	*Baseline*	*Fast*	*Slow*	*No Music*
A	2.7 (0.6)	2.7 (0.6)	2.3 (1.5)	2 (1)
B	0.5 (0)	0.5 (0)	0.5 (0)	1 (0.9)
C	0.8 (1)	1.7 (0.6)	1.5 (0.9)	1 (1)
D	1.7 (0.6)	**3** (0)	**3** (0)	1.3 (1.2)
E	1.3 (2.3)	1.3 (2.3)	1.2 (1.6)	**2.3** (2.1)
F	0.2 (0.3)	0.7 (1.2)	0.7 (1.2)	0.7 (1.2)
G	3.3 (0.6)	4 (1)	3 (1)	3 (0)
H	0.5 (0.5)	**1.3** (1.4)	1 (0.9)	0.8 (1)

Values in bold indicate that the subject's effort was higher than baseline.
The scores on the Modified Borg's Scale range from 0-10 with a lower score indicating less perceived effort.

Figures 4.1 to 4.8 show the gait velocity for all eight subjects for all conditions across sessions. The graphs are arranged according to the sessions (1, 2 and 3). Each of the graphs shows data points indicating gait speed (cm/s) across conditions. The number of trials in each condition is different for each subject. This is because the subjects walked and completed as many trials they could in three minutes. A regression line has been drawn for data points in each condition. This indicates the direction of the data path. The red line indicates the mean level for the data points in that particular condition. A line has been drawn through the median of the baseline condition and this has been extended through all conditions. This line has been used in the split middle analysis.

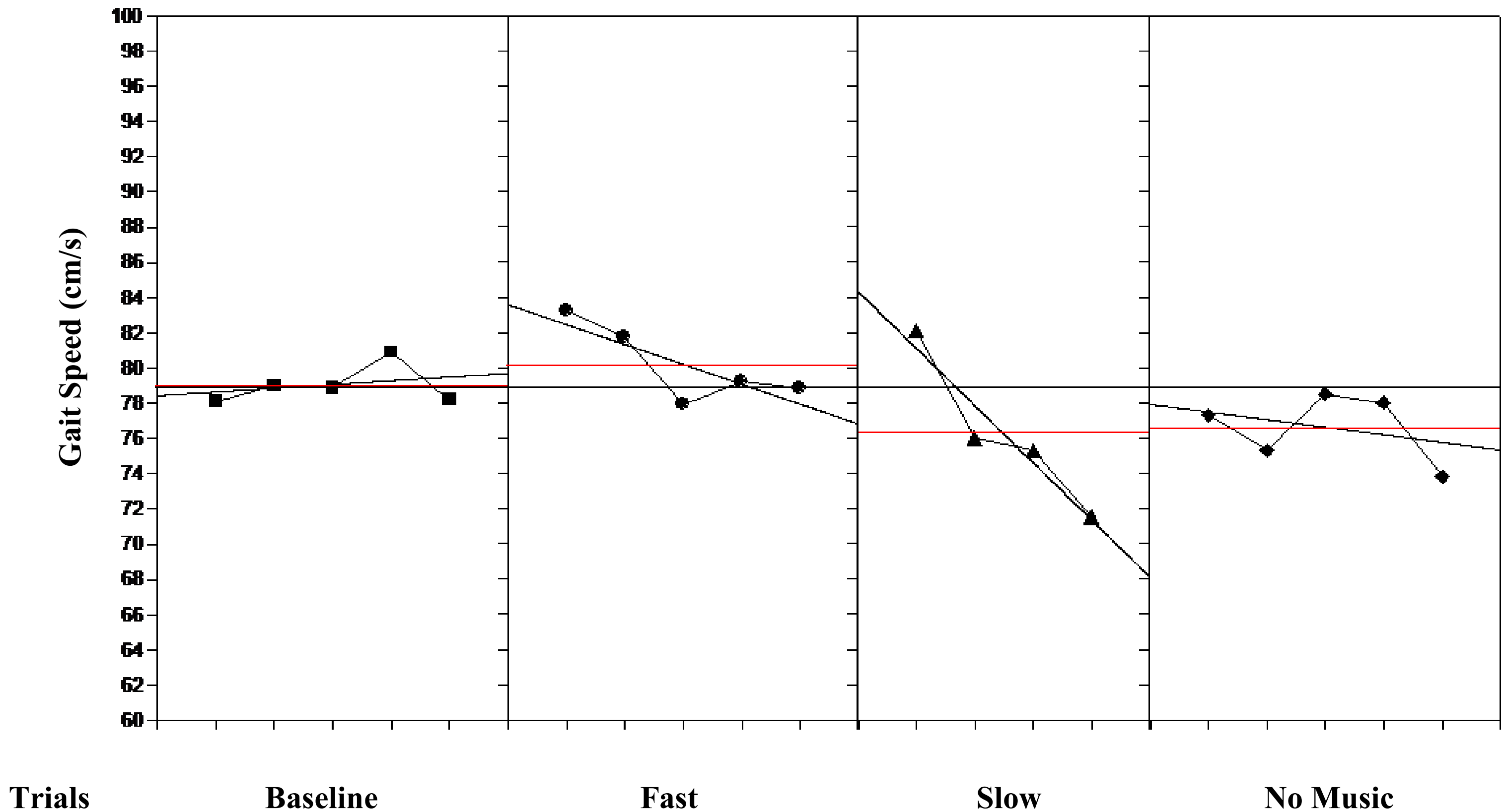

Figure 4.1 (a): Gait speed of Subject A for Session 1. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

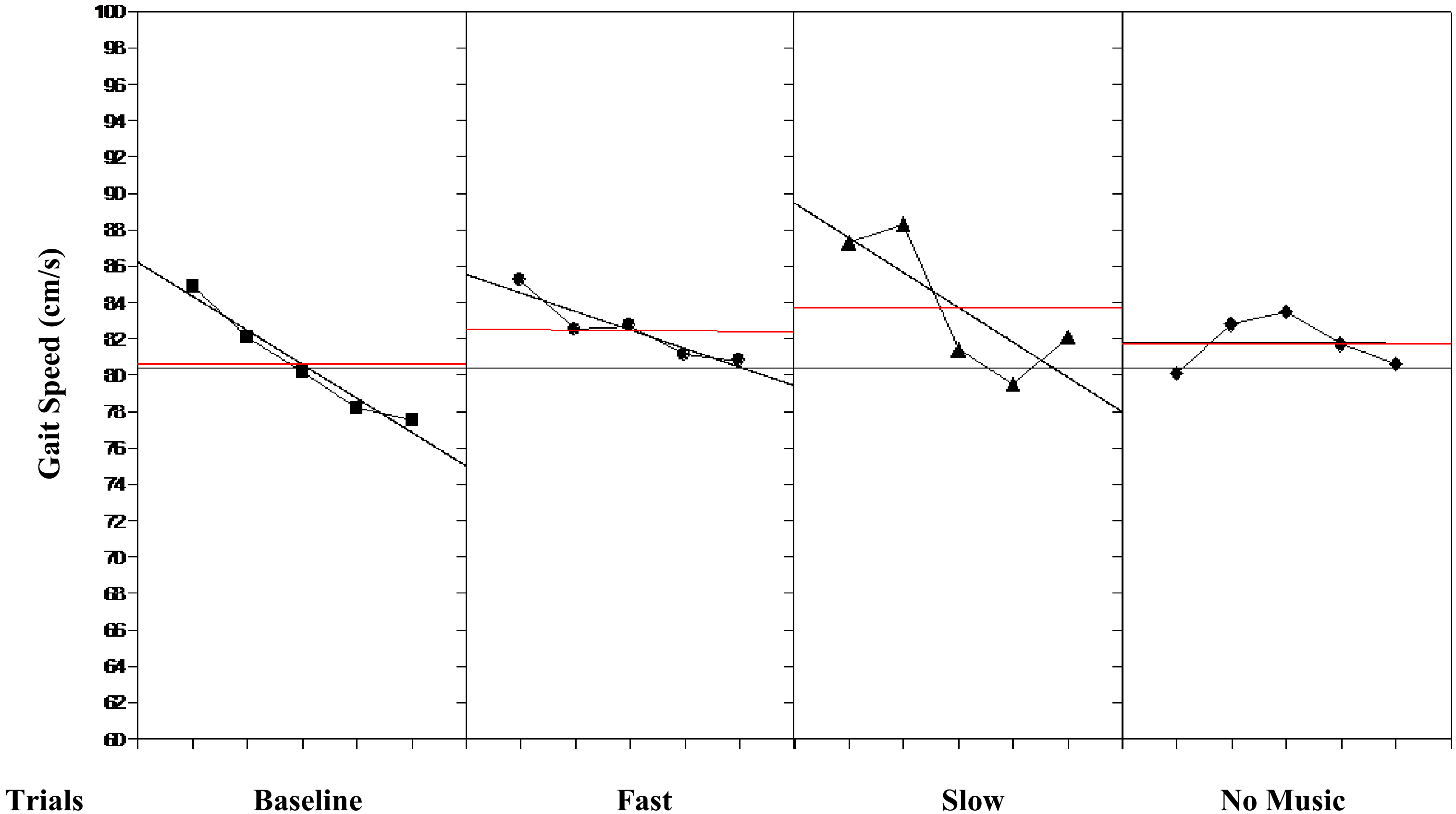

Figure 4.1 (b): Gait speed of Subject A for Session 2. Music conditions were presented in the following order – Slow Music, Fast Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

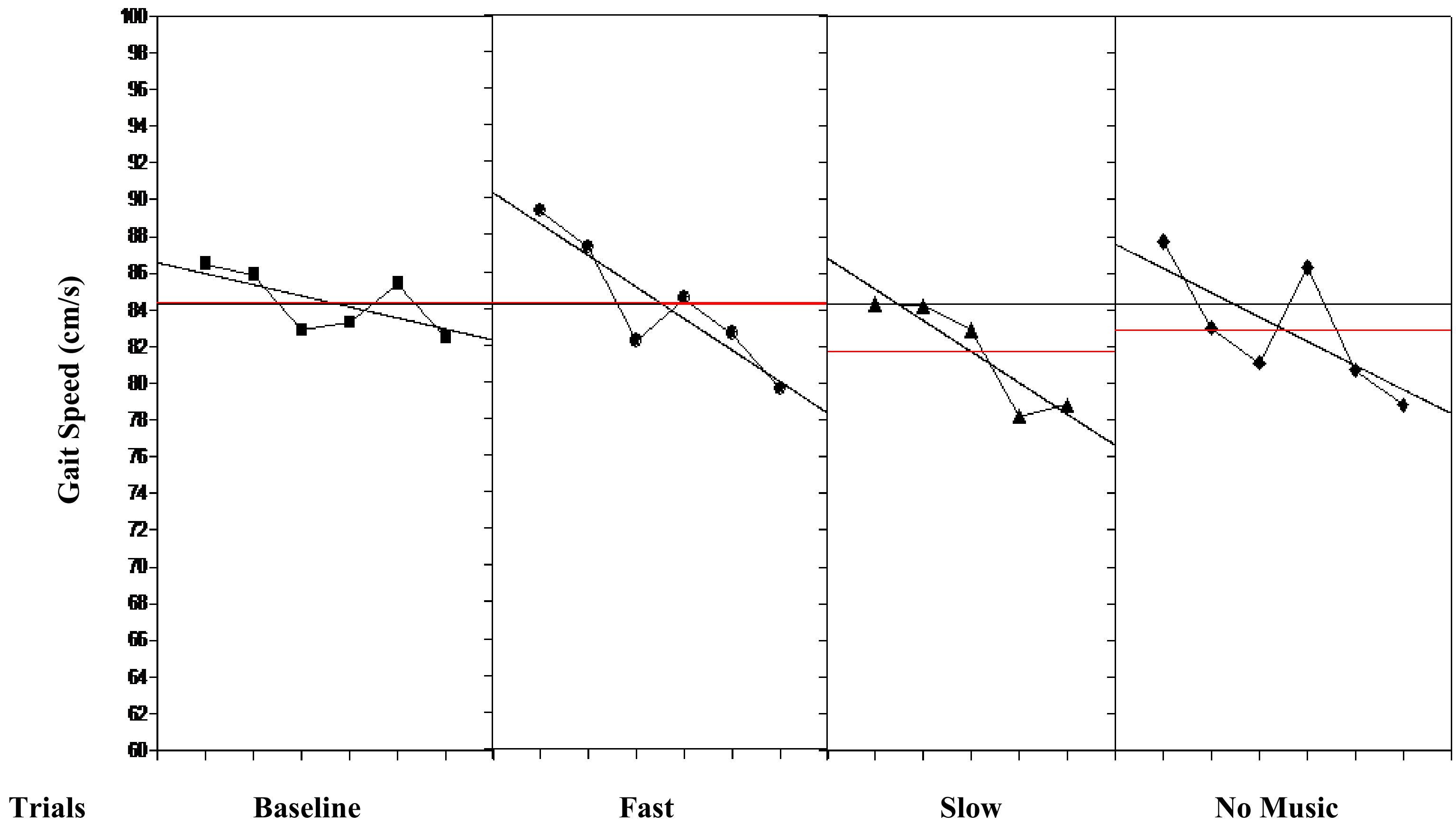

Figure 4.1 (c): Gait speed of Subject A for Session 3. Music conditions were presented in the following order – Fast Music, Slow Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

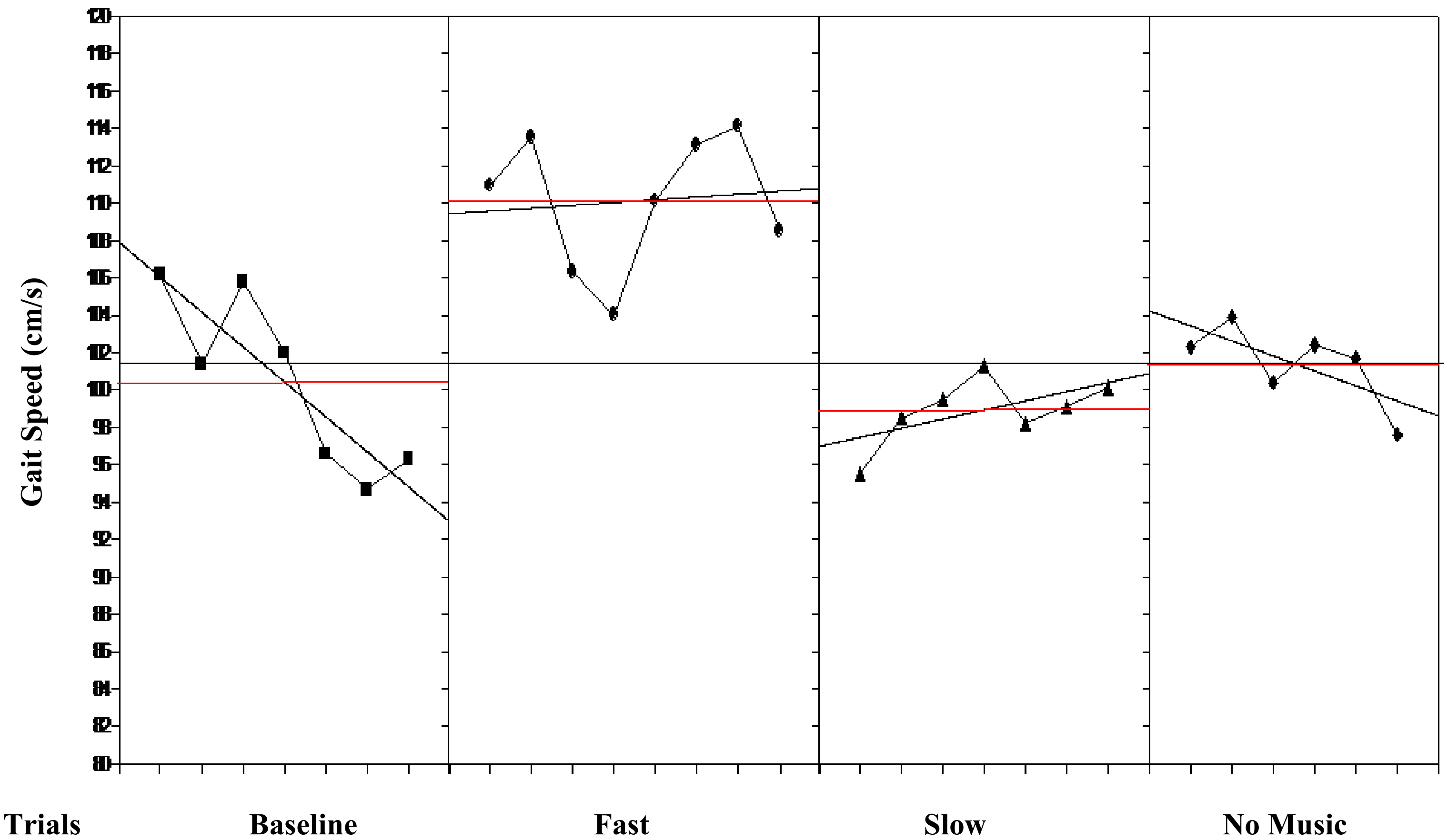

Figure 4.2 (a): Gait speed of Subject B for Session 1. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

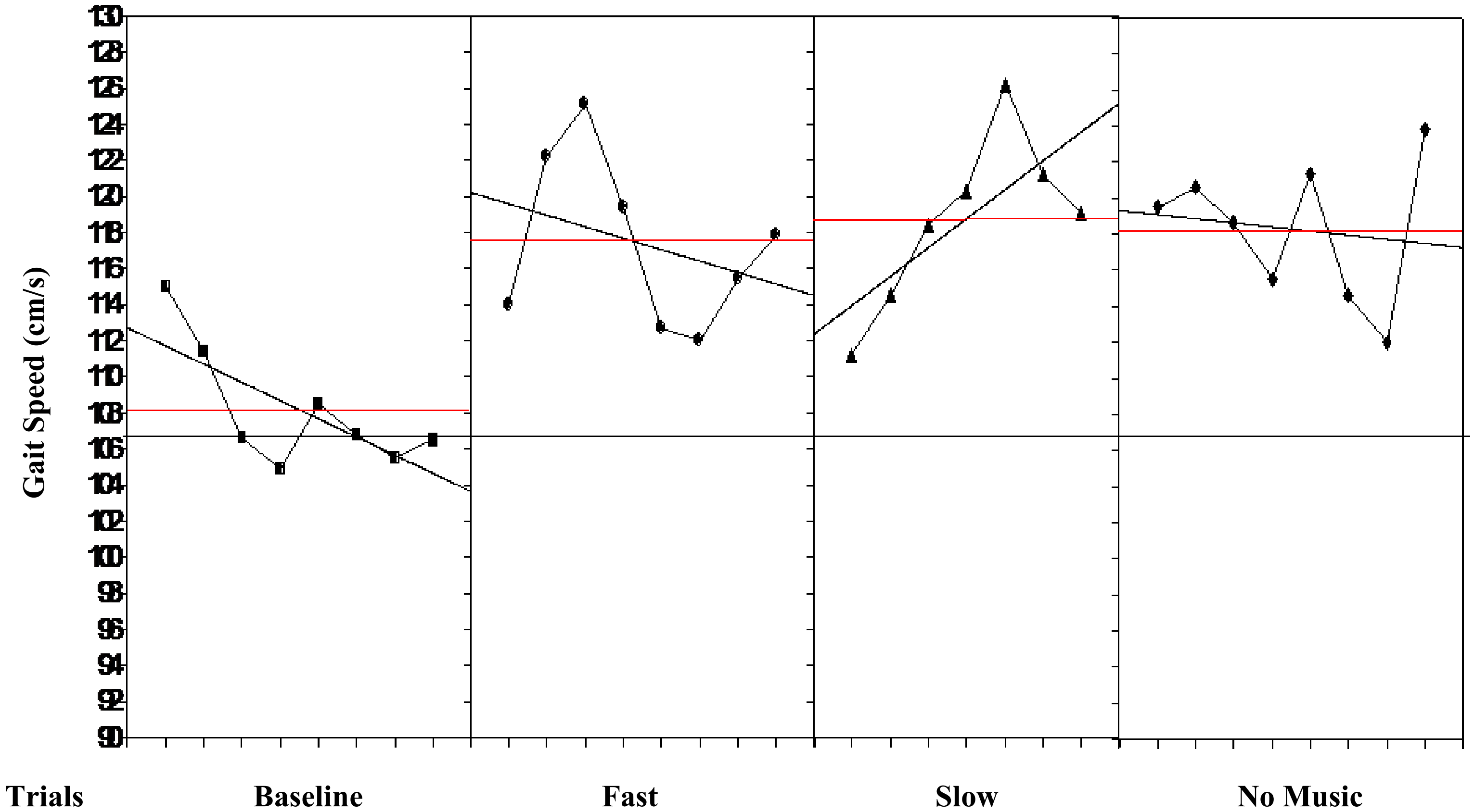

Figure 4.2 (b): Gait speed of Subject B for Session 2. Music conditions were presented in the following order – Slow Music, Fast Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

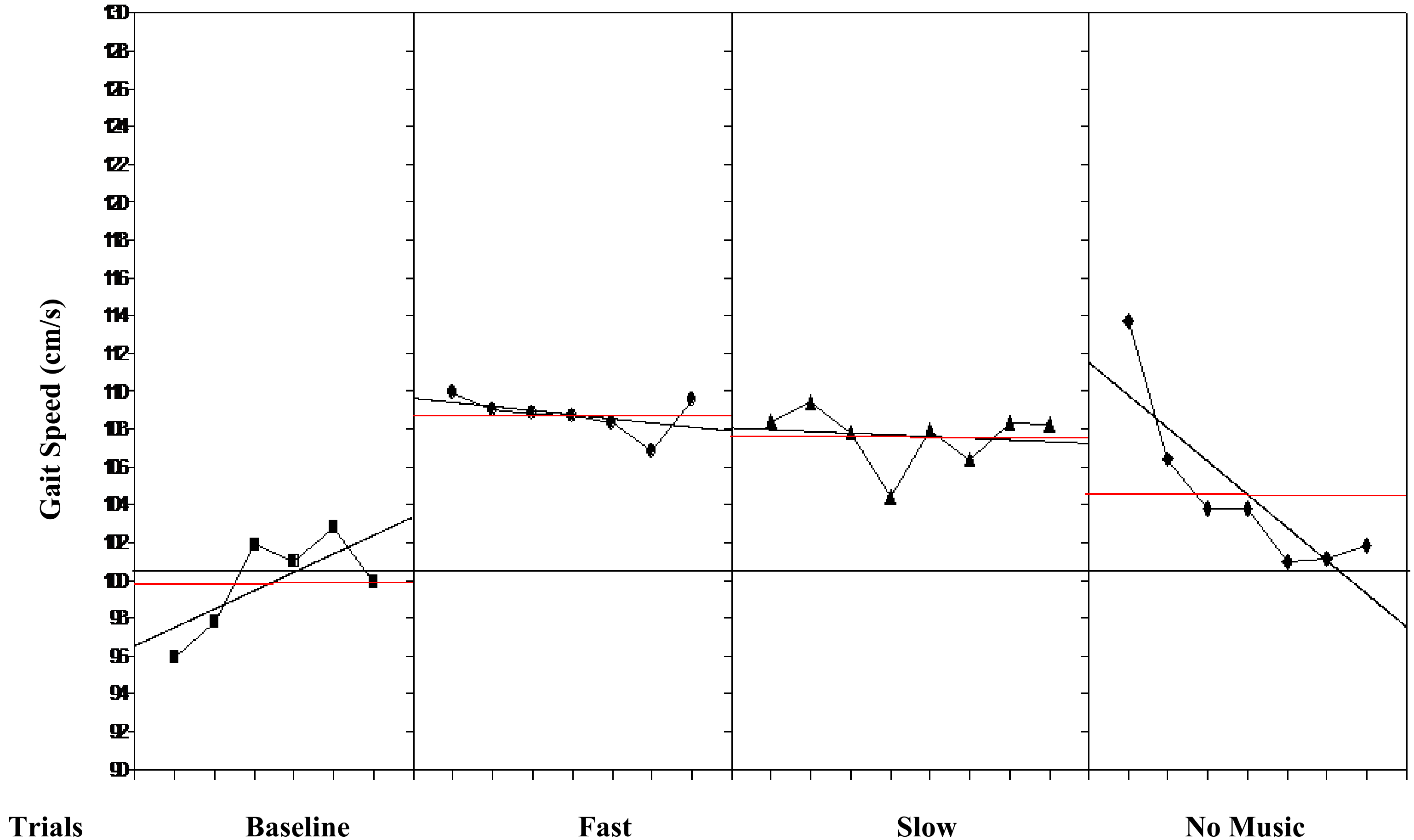

Figure 4.2 (c): Gait speed of Subject B for Session 3. Music conditions were presented in the following order – No Music, Fast Music and Slow Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

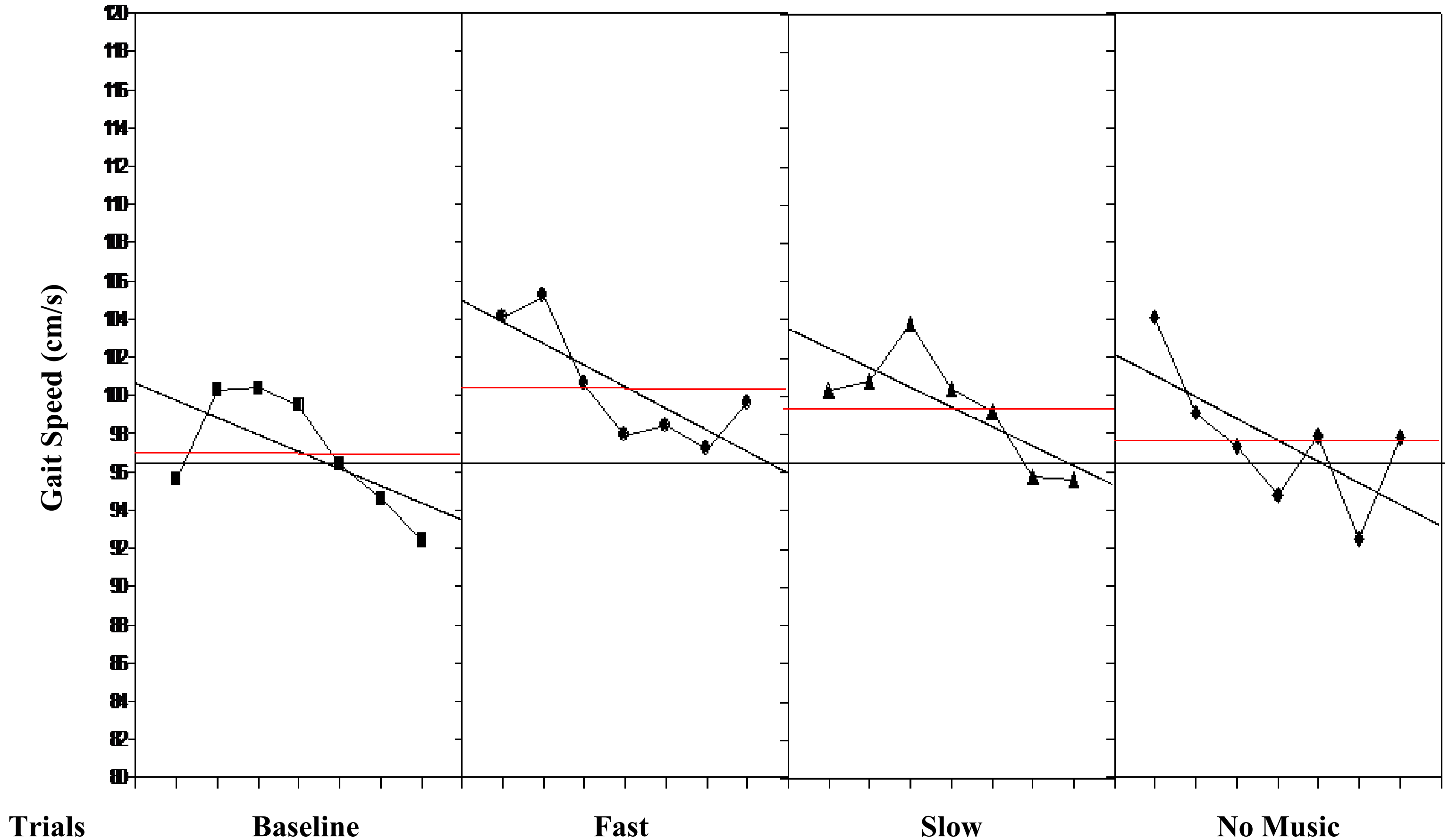

Figure 4.3 (a): Gait speed of Subject C for Session 1. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

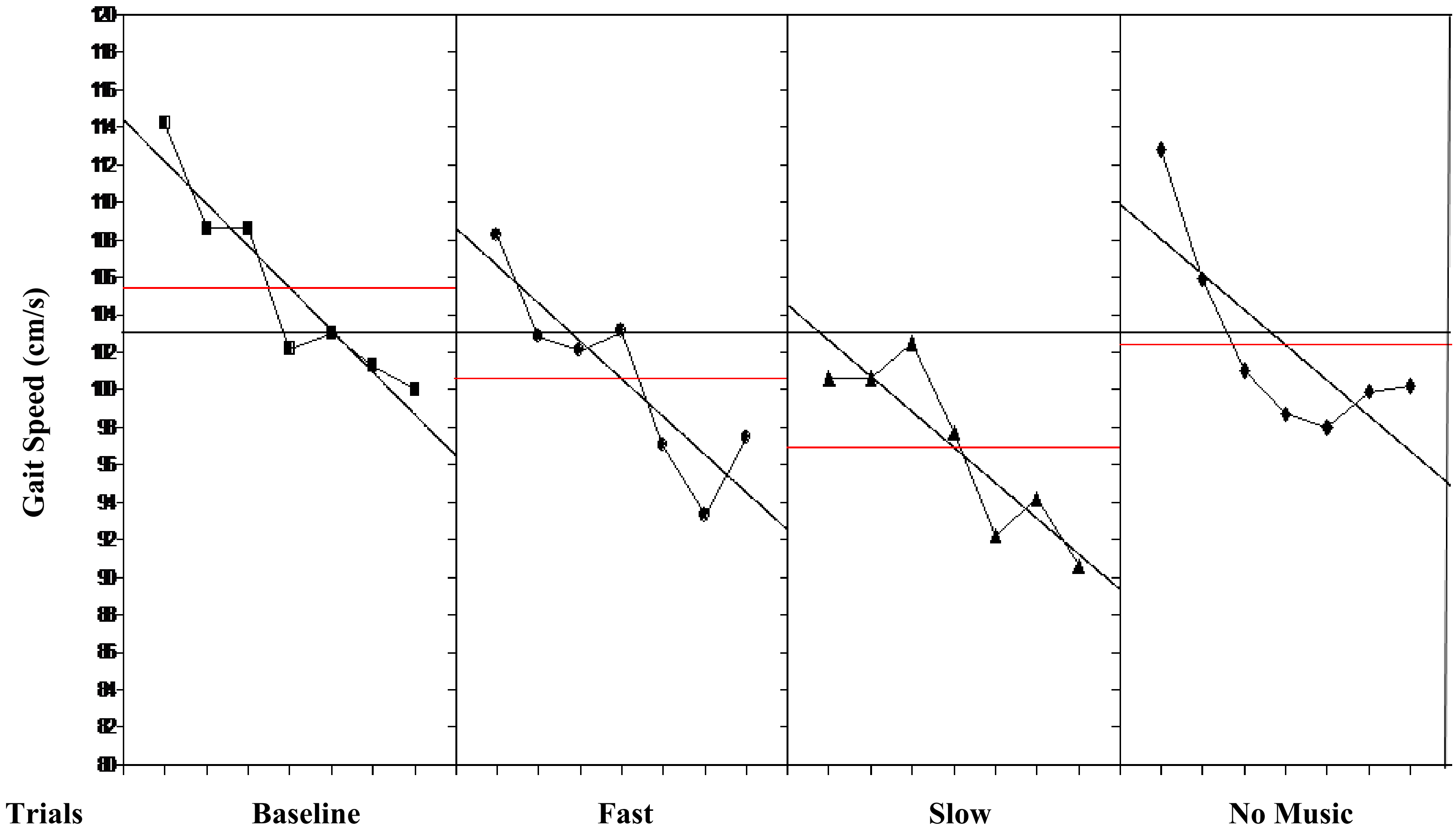

Figure 4.3 (b): Gait speed of Subject C for Session 2. Music conditions were presented in the following order – No Music, Fast Music and Slow Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

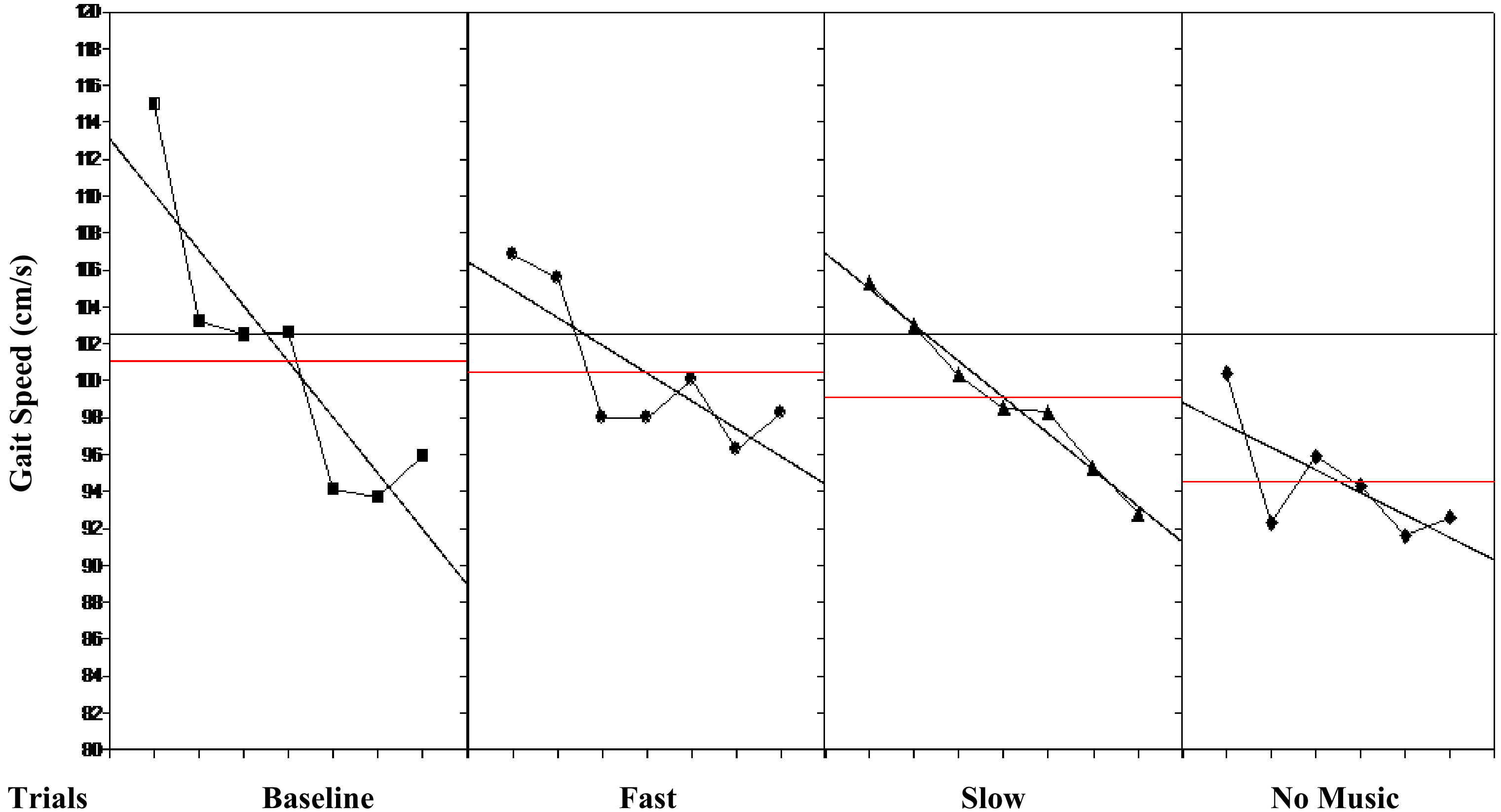

Figure 4.3 (c): Gait speed of Subject C for Session 3. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

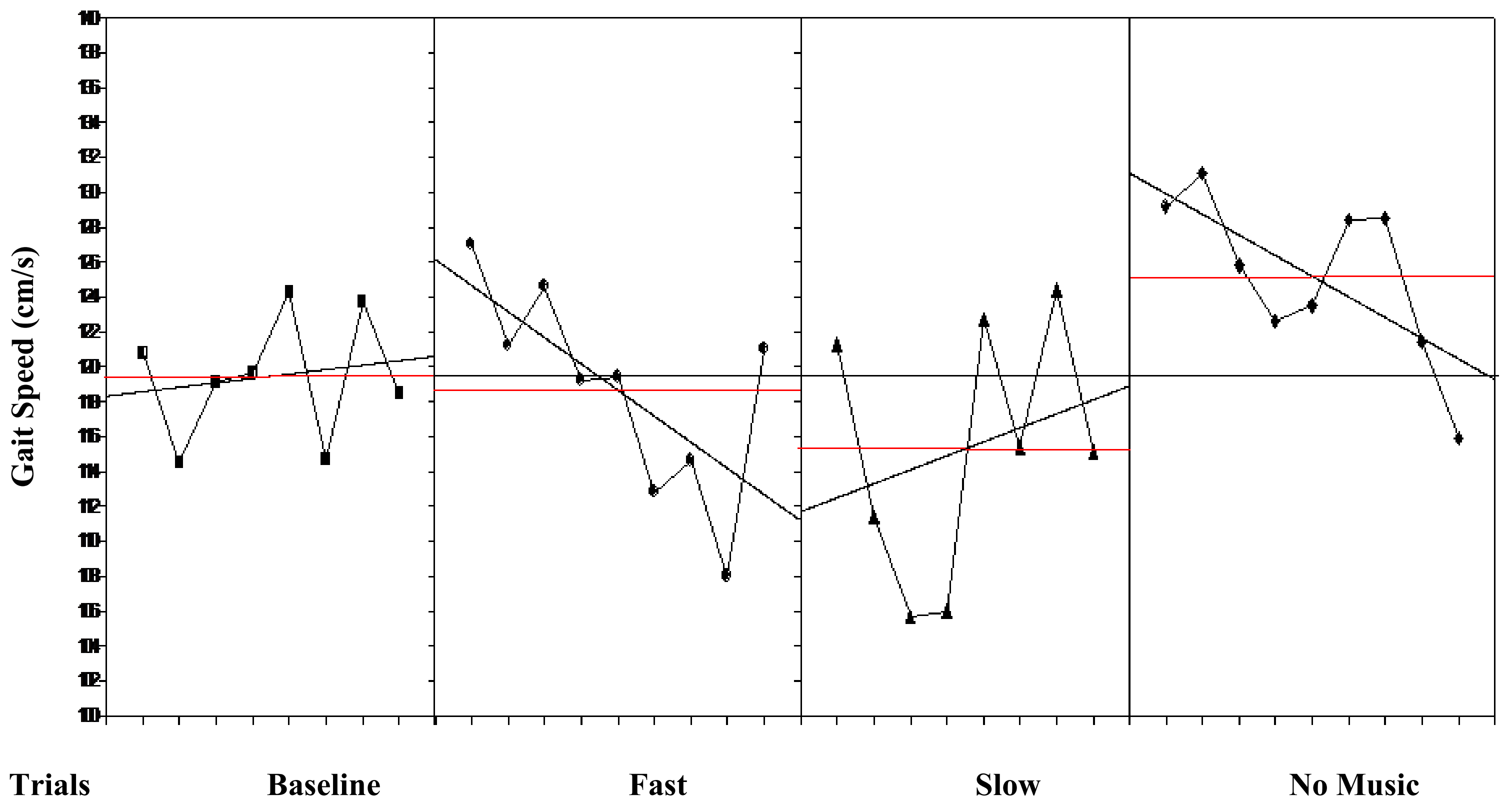

Figure 4.4 (a): Gait speed of Subject D for Session 1. Music conditions were presented in the following order – Fast Music, Slow Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

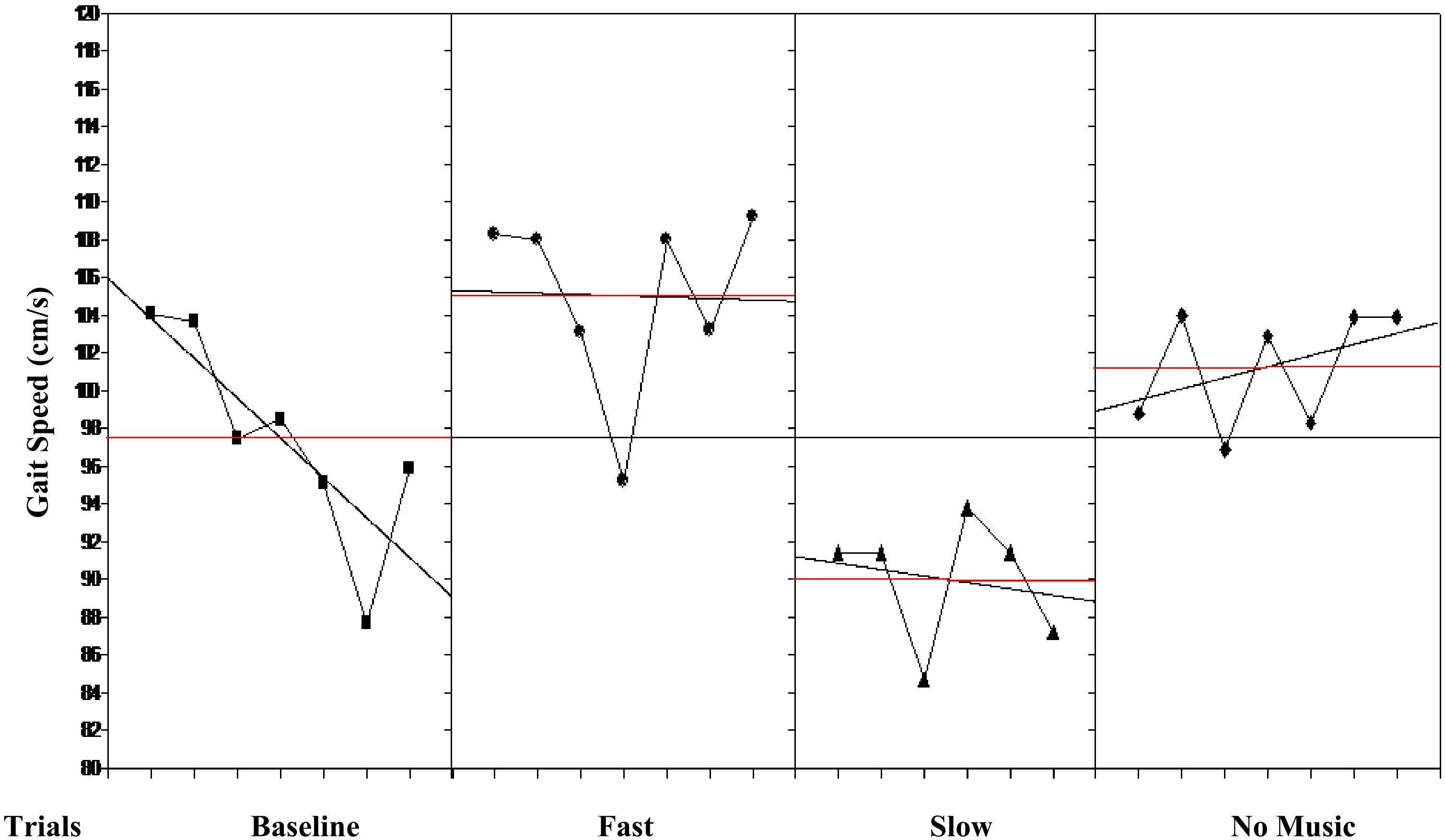

Figure 4.4 (b): Gait speed of Subject D for Session 2. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

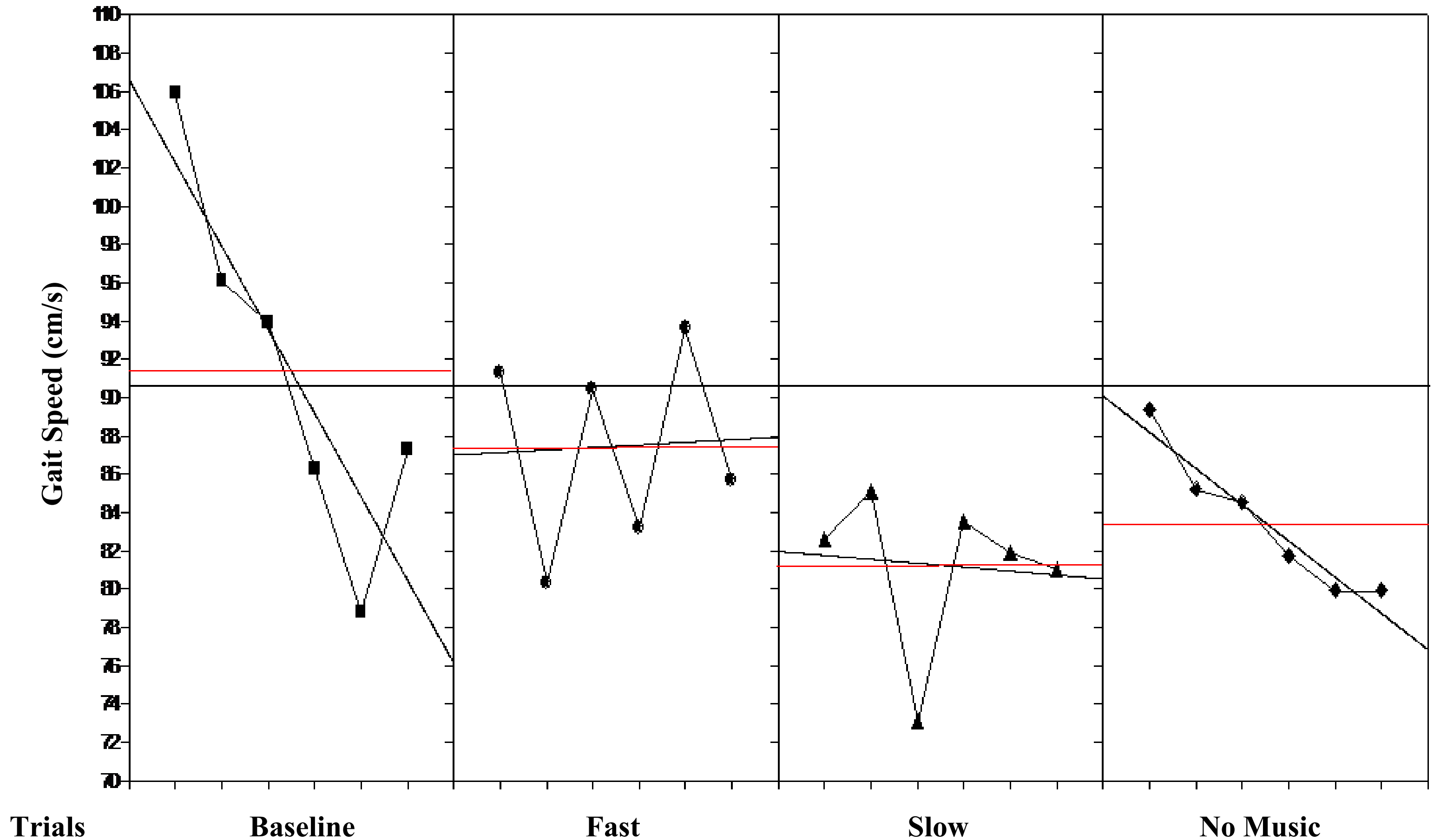

Figure 4.4 (c): Gait speed of Subject D for Session 3. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

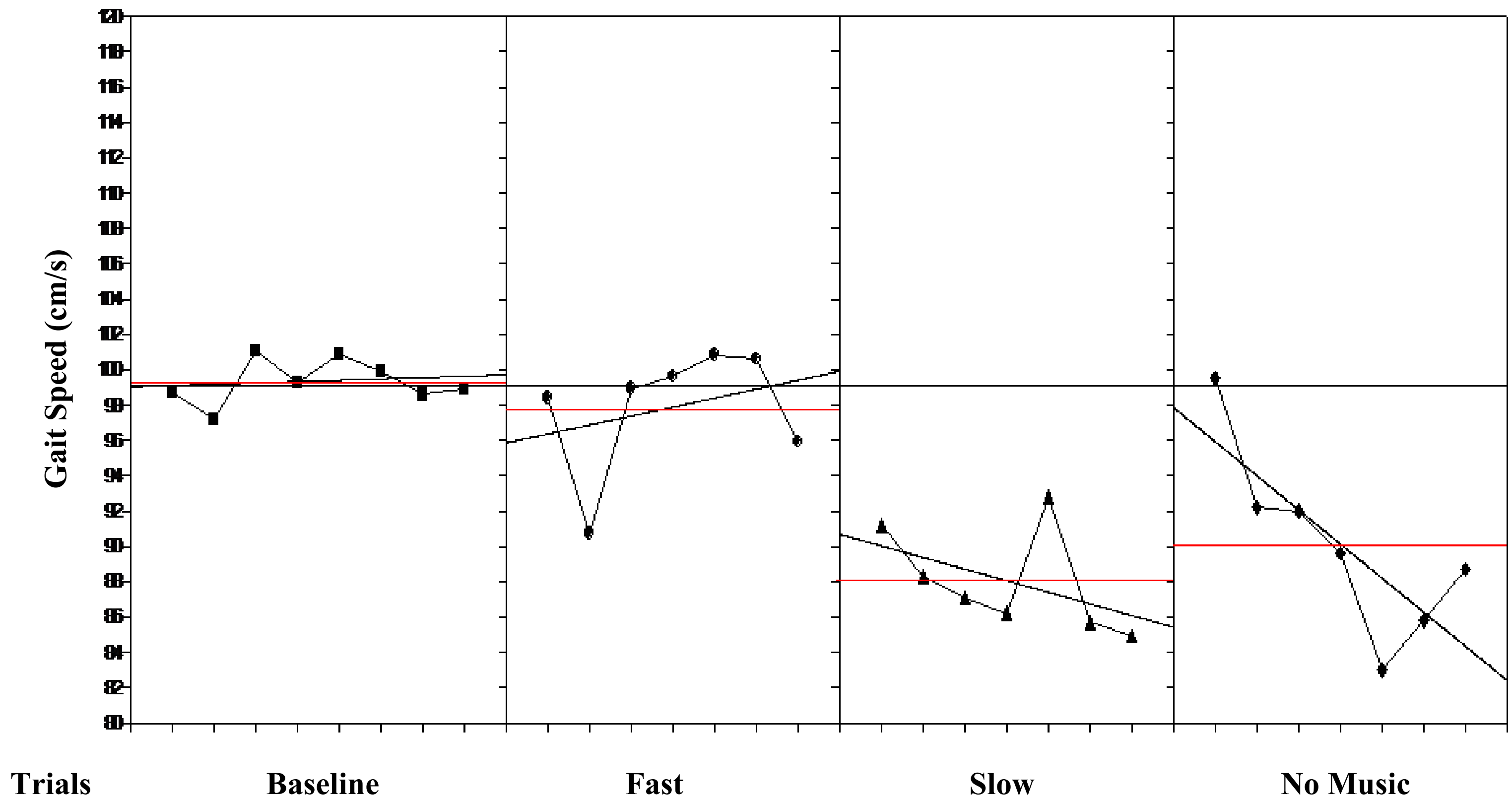

Figure 4.5 (a): Gait speed of Subject E for Session 1. Music conditions were presented in the following order – No Music, Fast Music and Slow Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

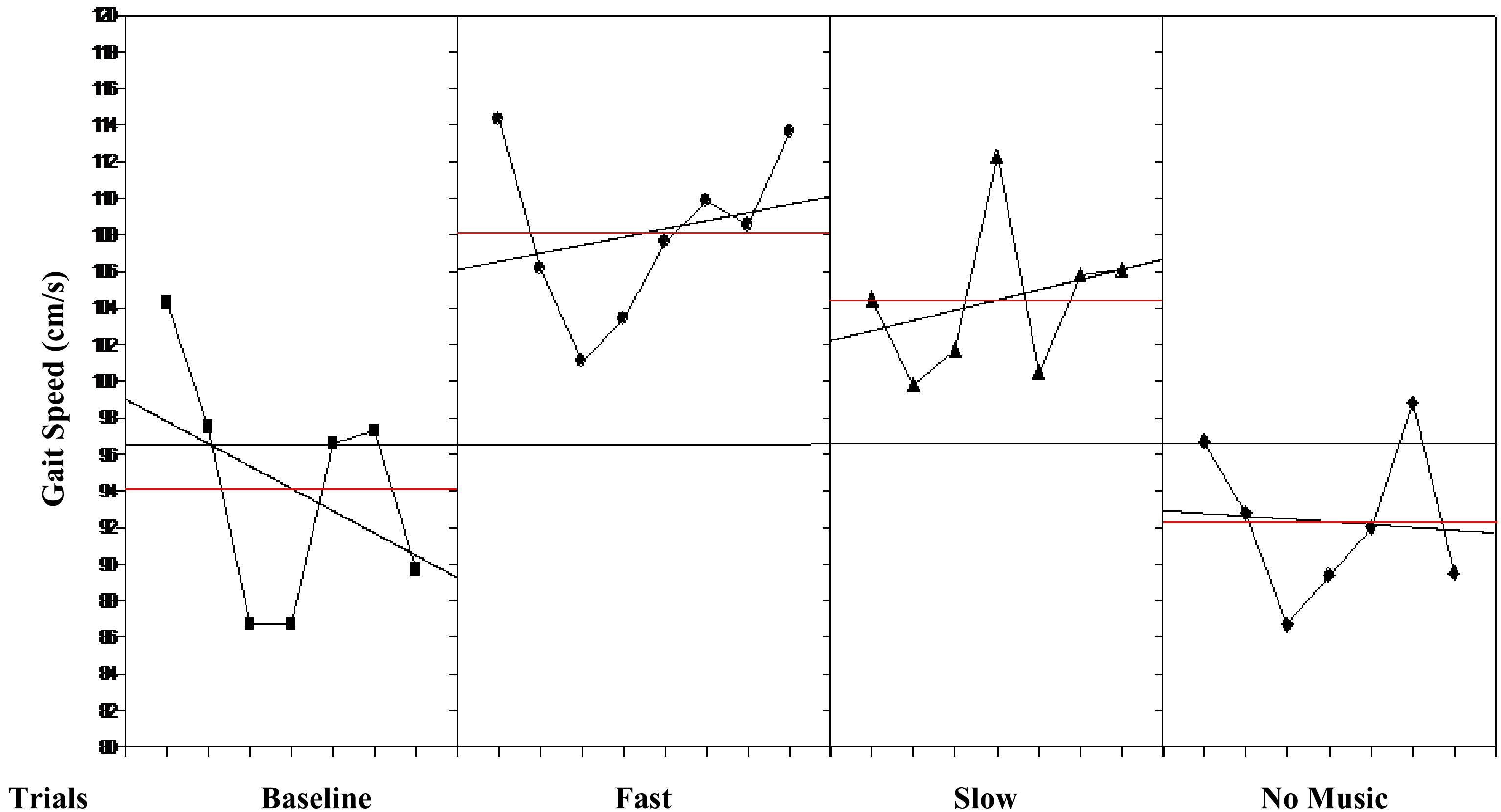

Figure 4.5 (b): Gait speed of Subject E for Session 2. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

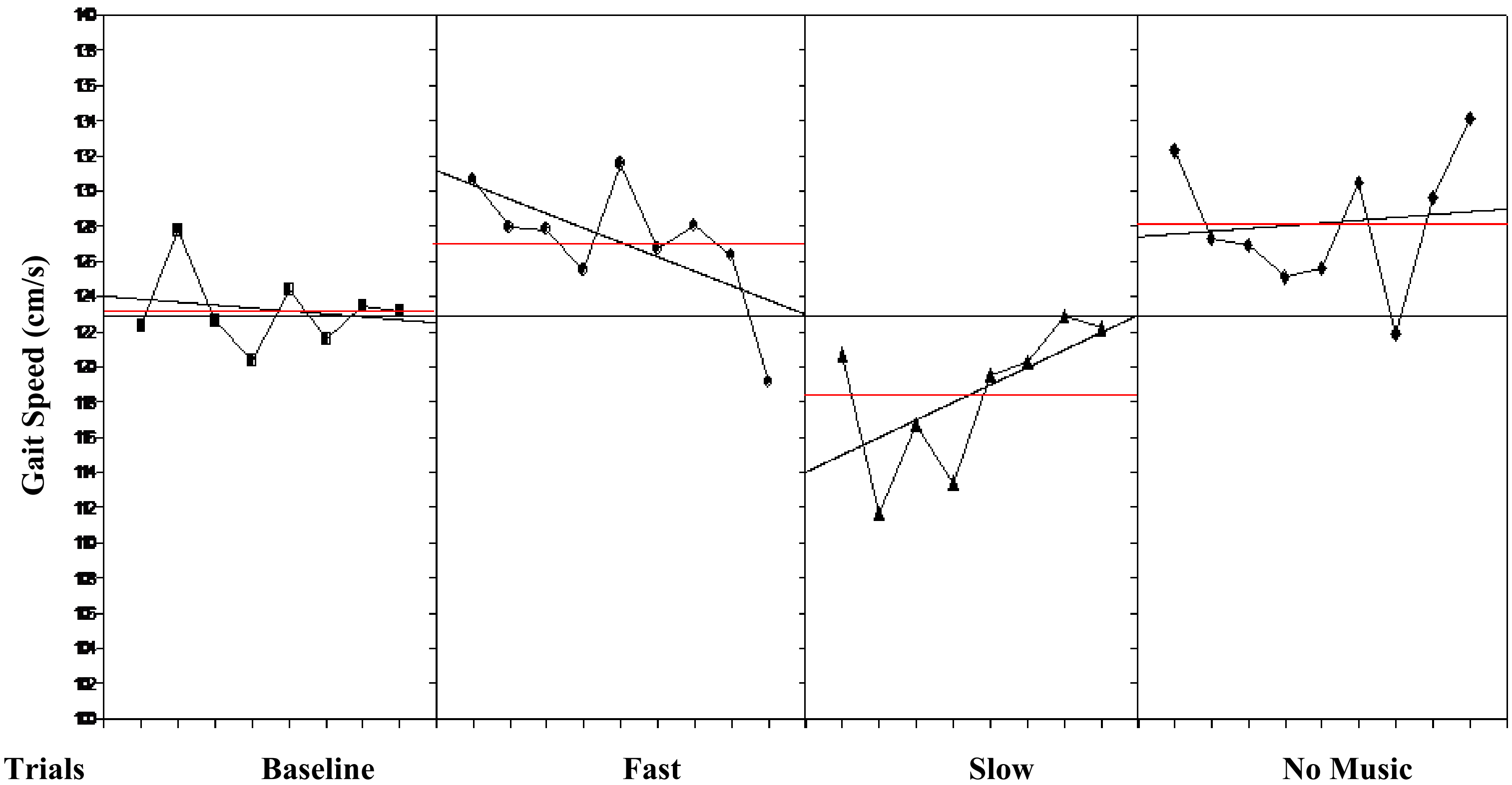

Figure 4.5 (c): Gait speed of Subject E for Session 3. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

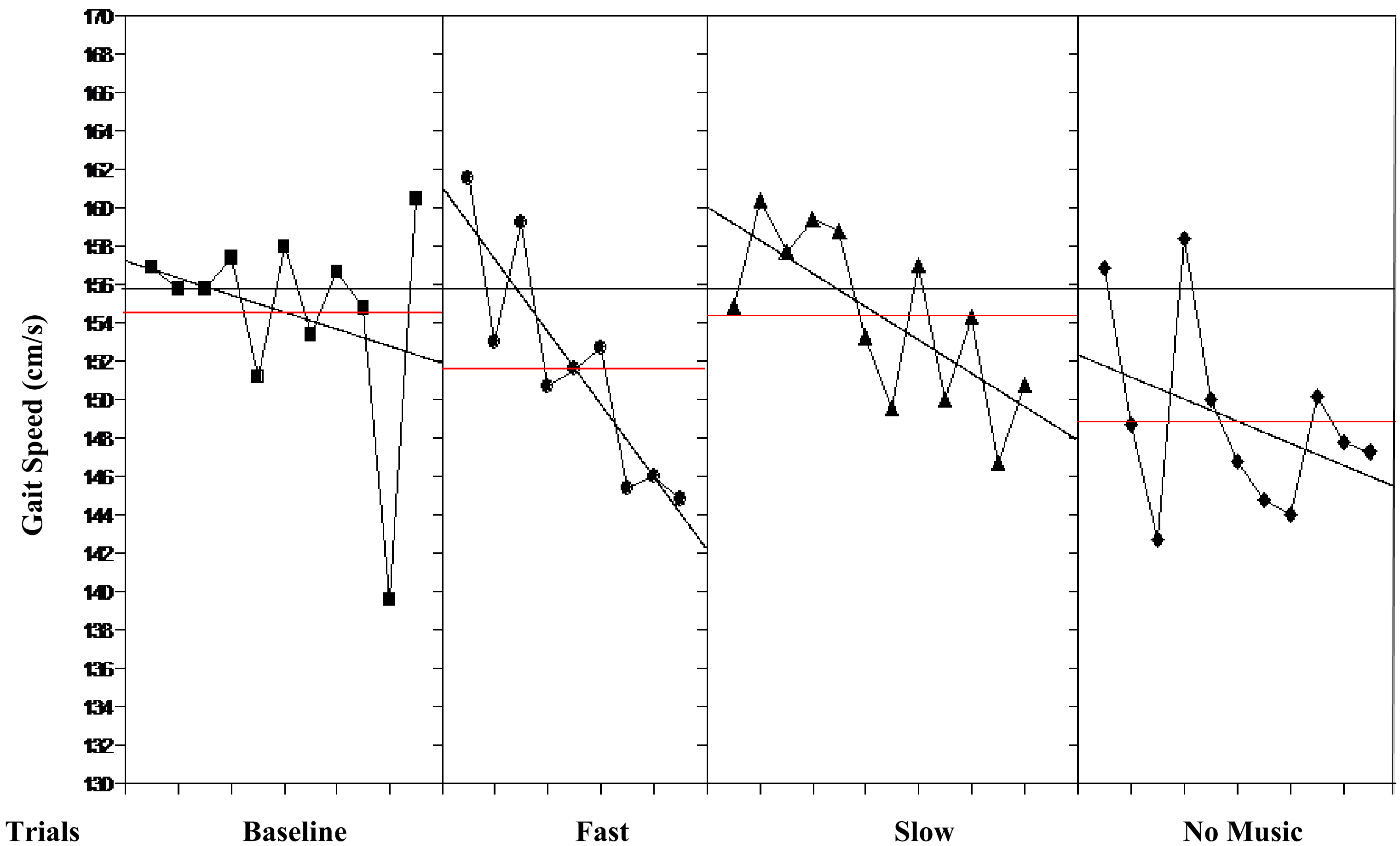

Figure 4.6 (a): Gait speed of Subject F for Session 1. Music conditions were presented in the following order – No Music, Fast Music and Slow Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

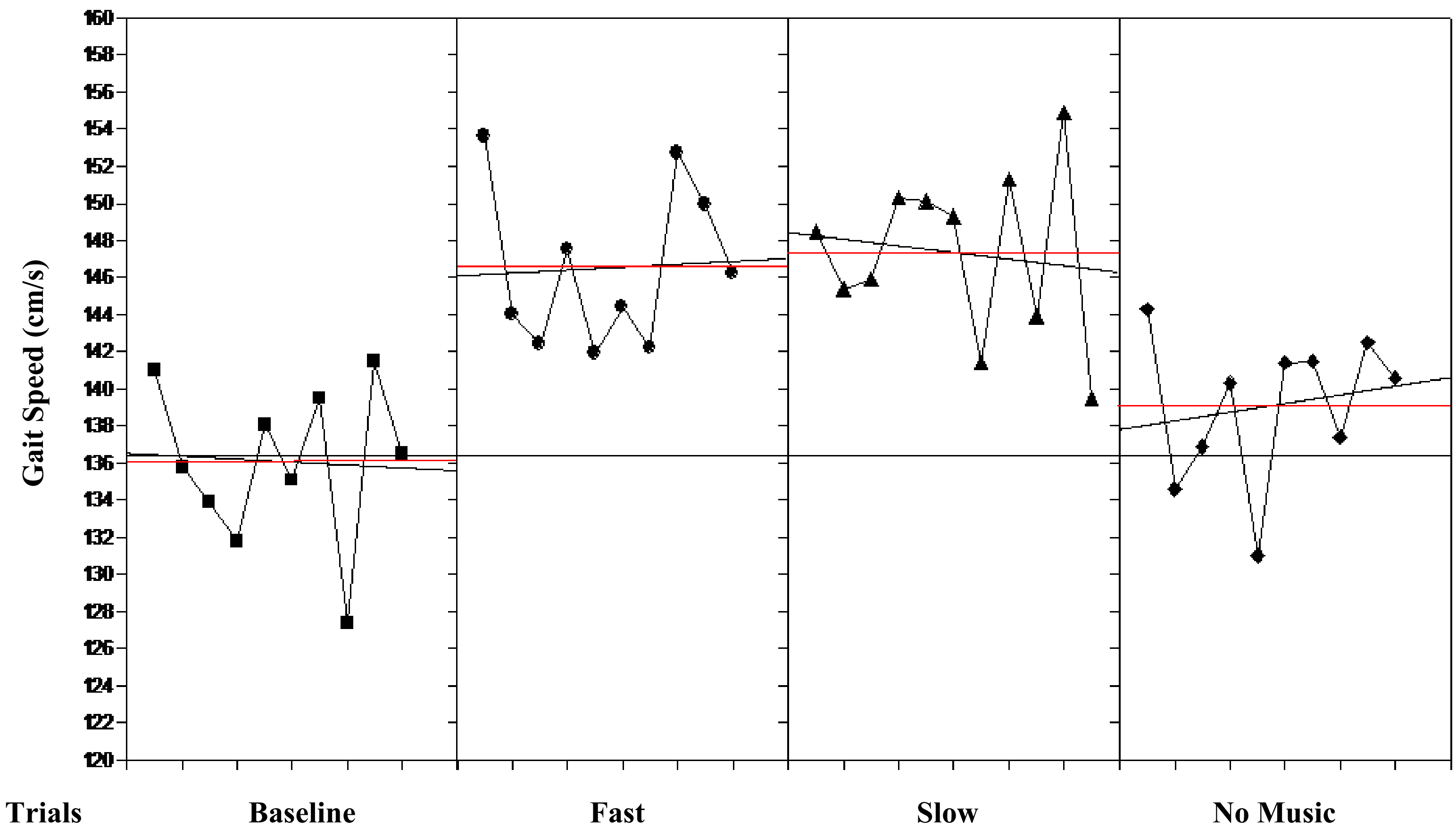

Figure 4.6 (b): Gait speed of Subject F for Session 2. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

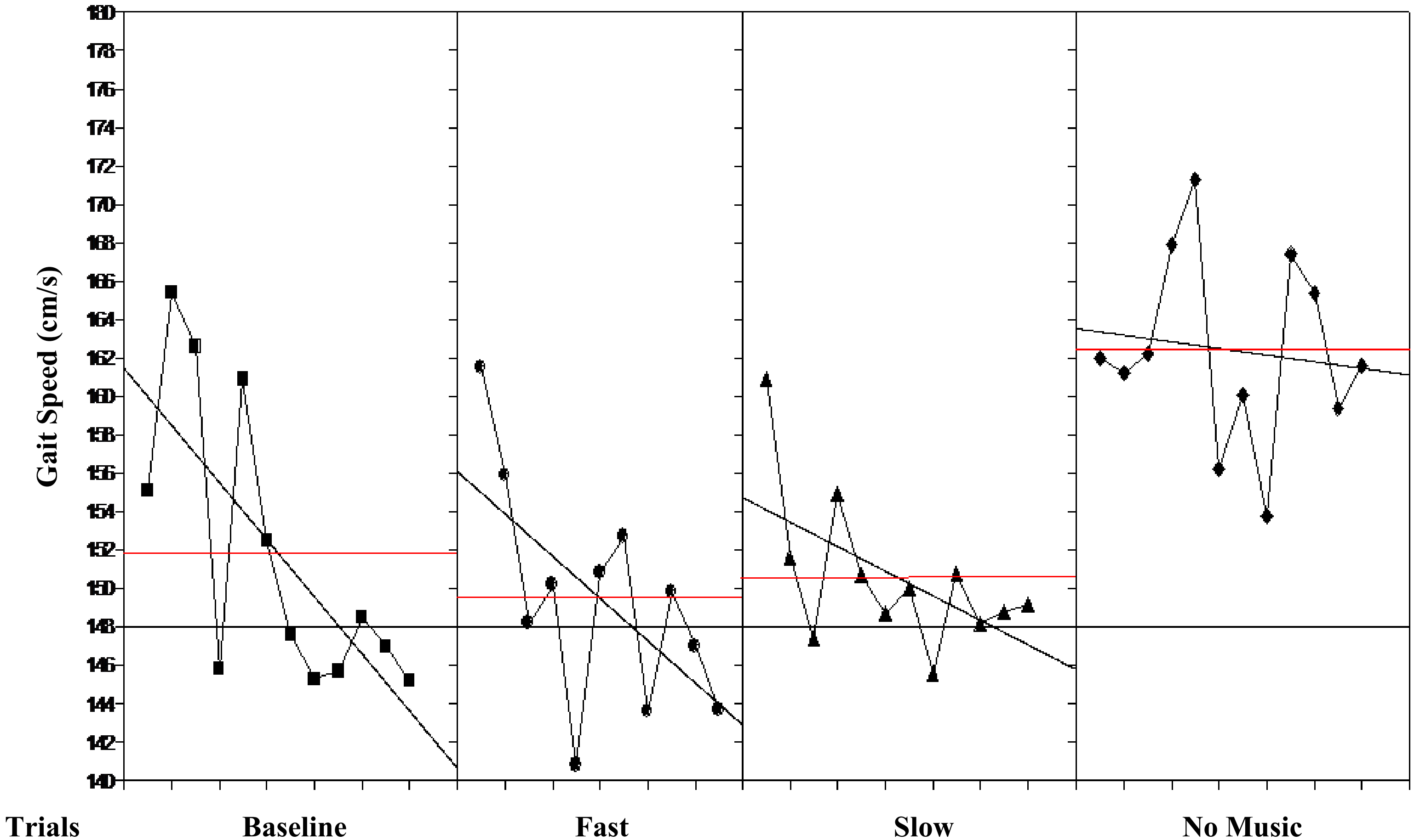

Figure 4.6 (c): Gait speed of Subject F for Session 3. Music conditions were presented in the following order – Fast Music, Slow Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

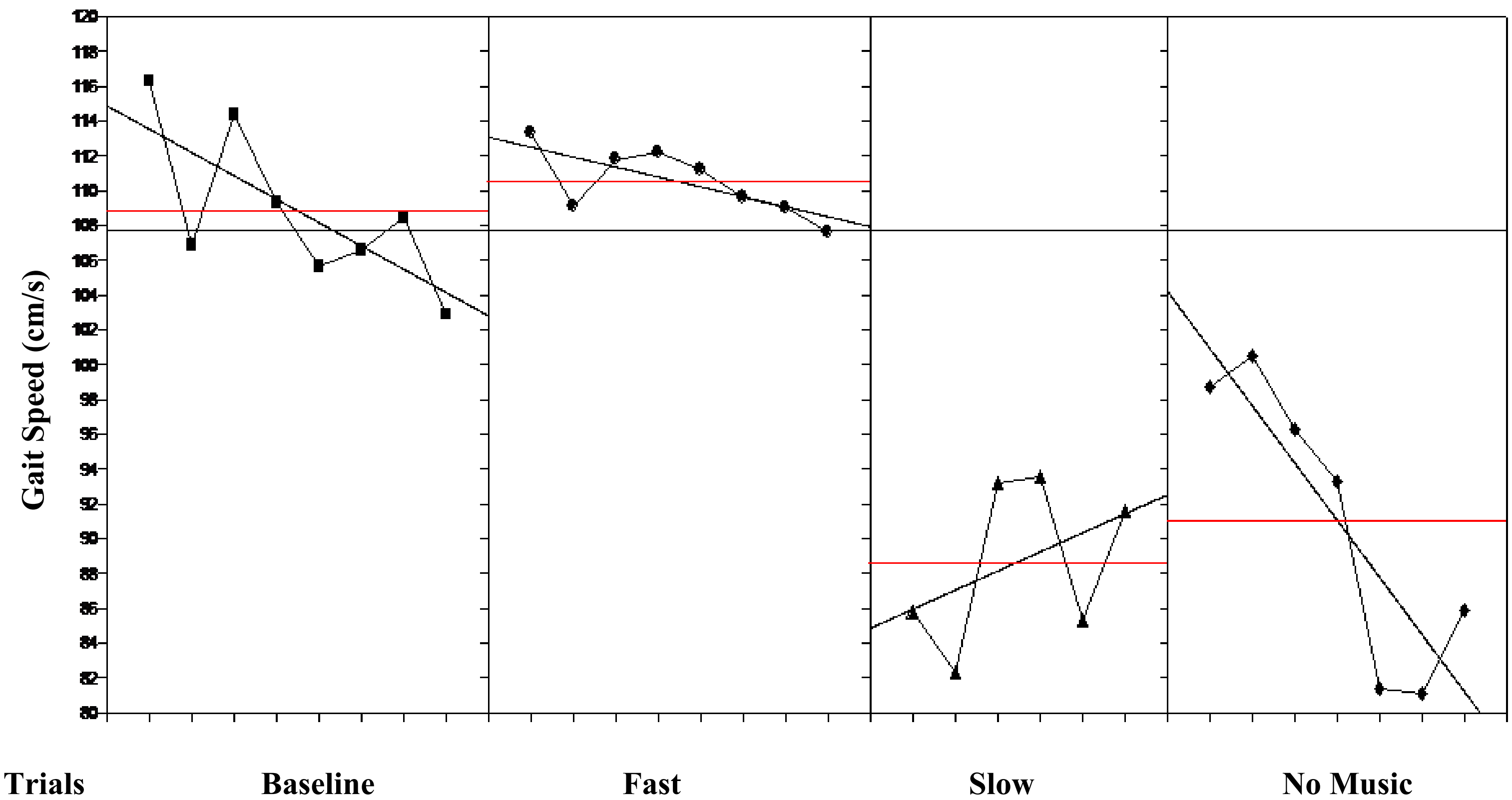

Figure 4.7 (a): Gait speed of Subject G for Session 1. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

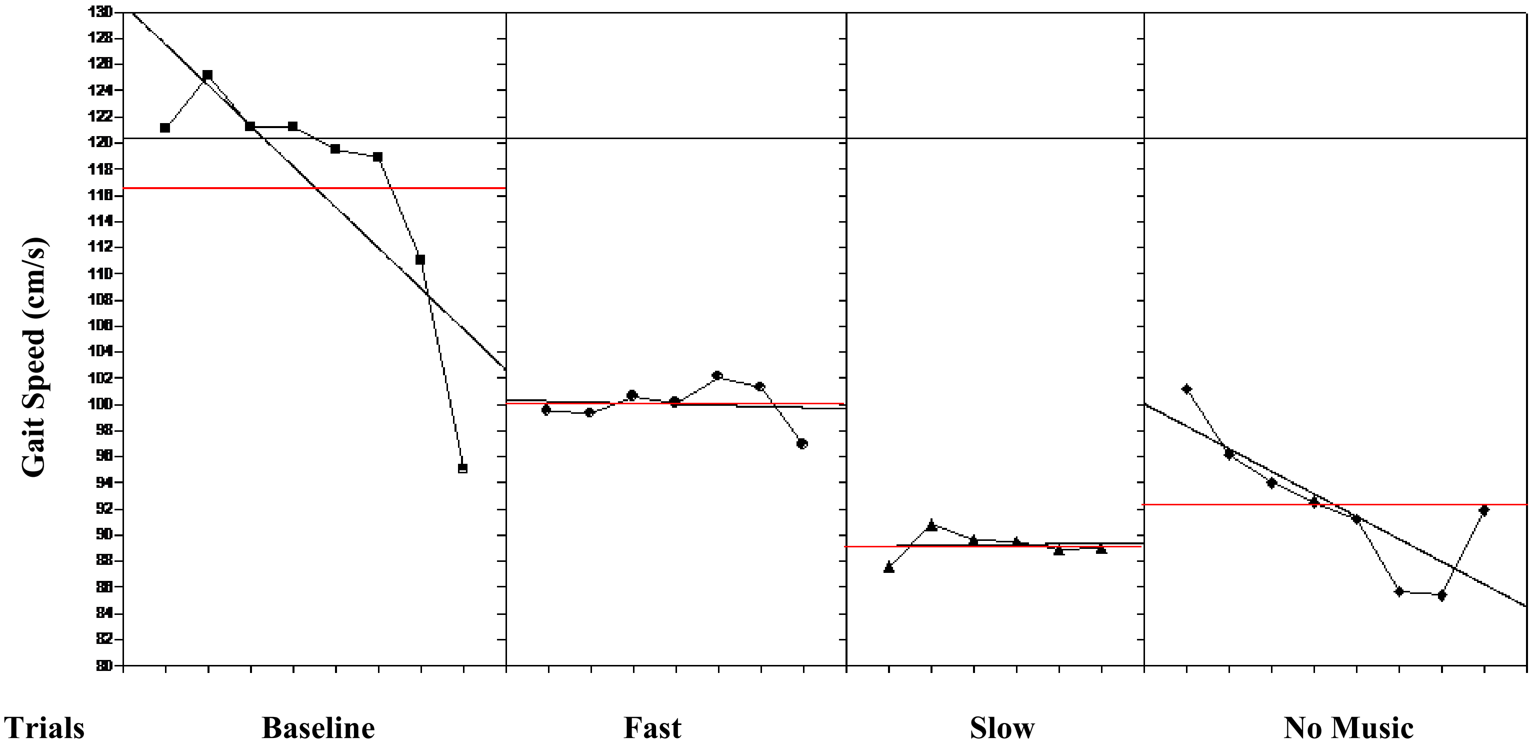

Figure 4.7 (b): Gait speed of Subject G for Session 2. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

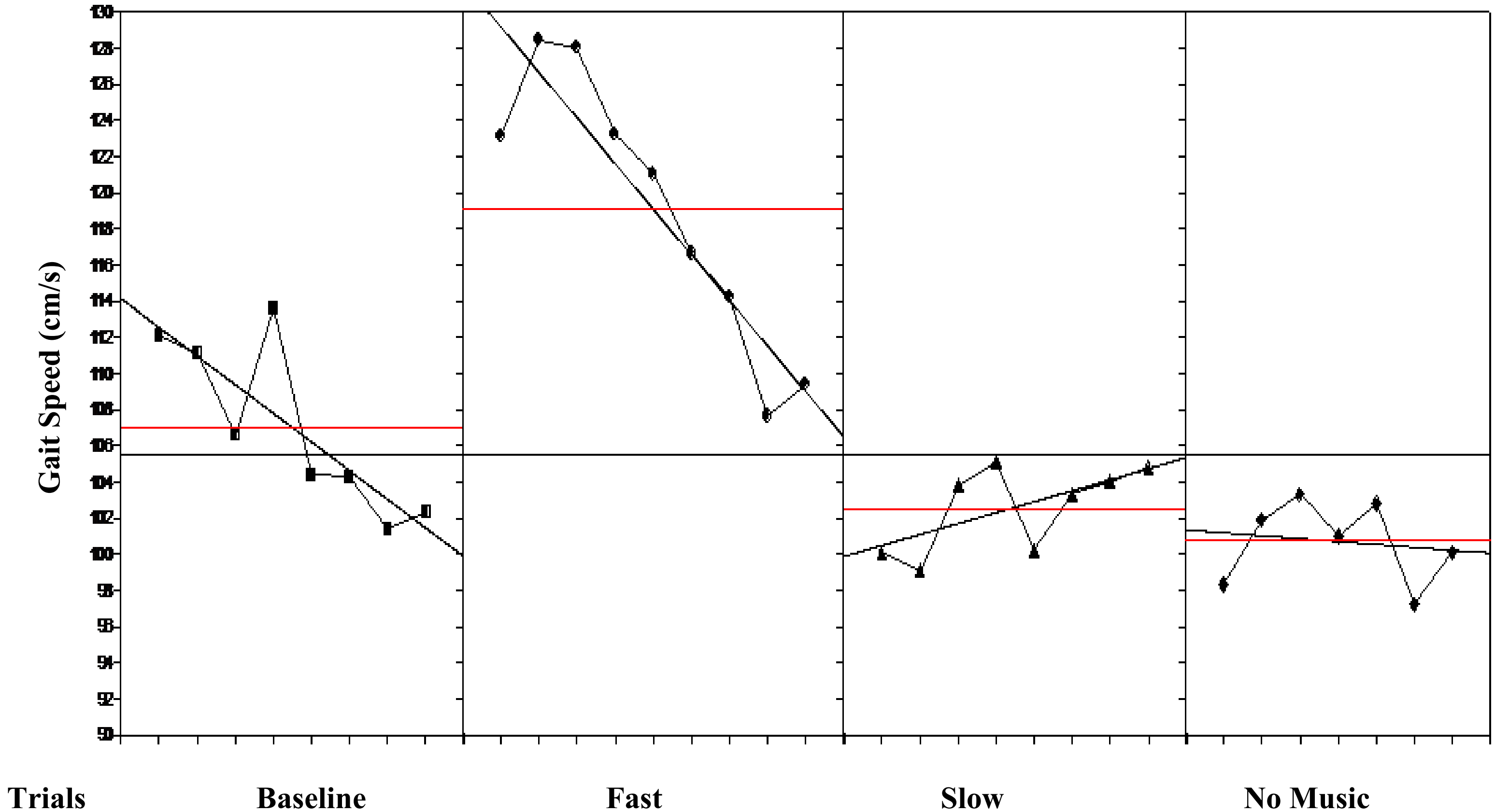

Figure 4.7 (c): Gait speed of Subject G for Session 3. Music conditions were presented in the following order – Fast Music, No Music and Slow Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

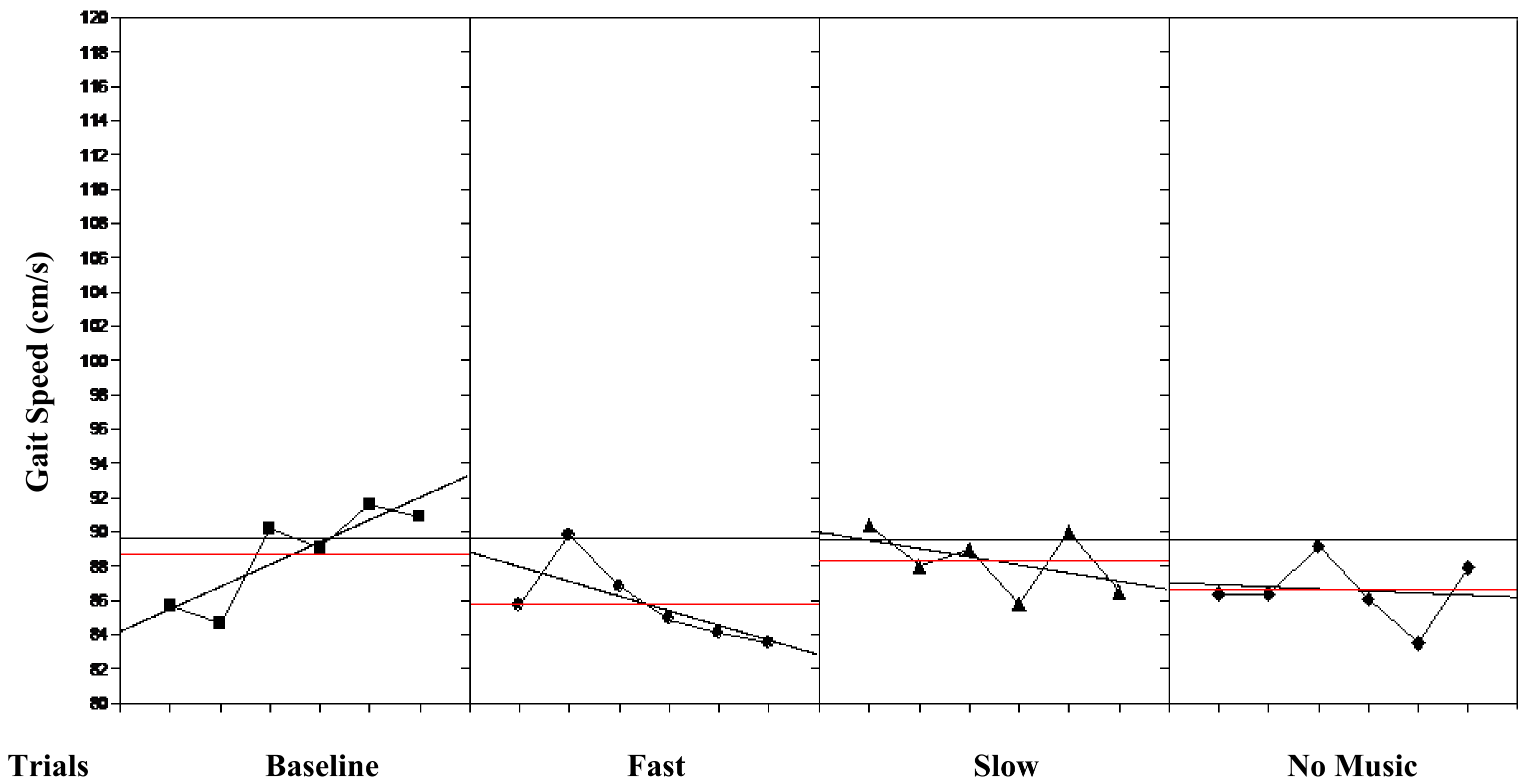

Figure 4.8 (a): Gait speed of Subject H for Session 1. Music conditions were presented in the following order – No Music, Slow Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

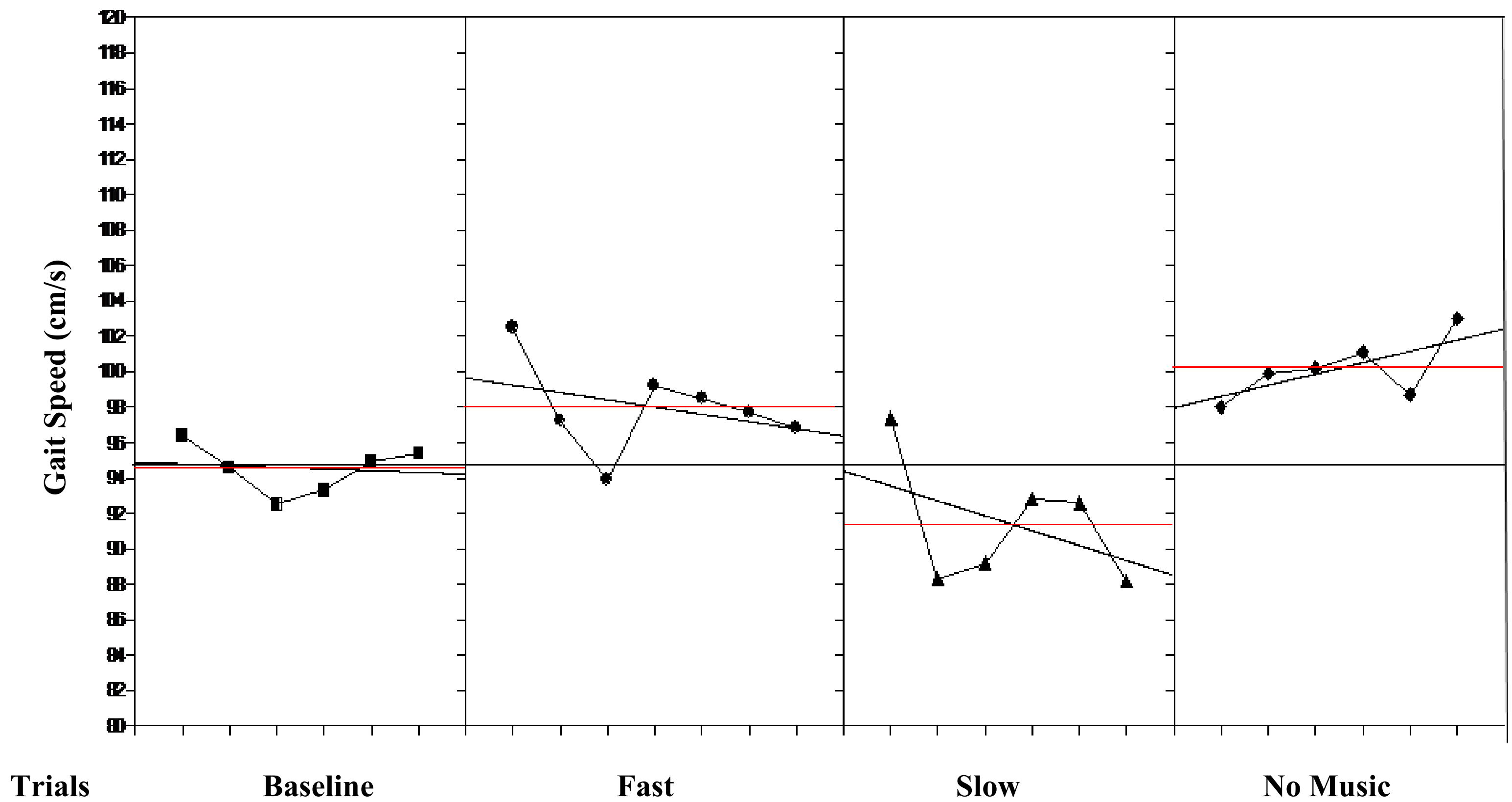

Figure 4.8 (b): Gait speed of Subject H for Session 2. Music conditions were presented in the following order – Slow Music, No Music and Fast Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

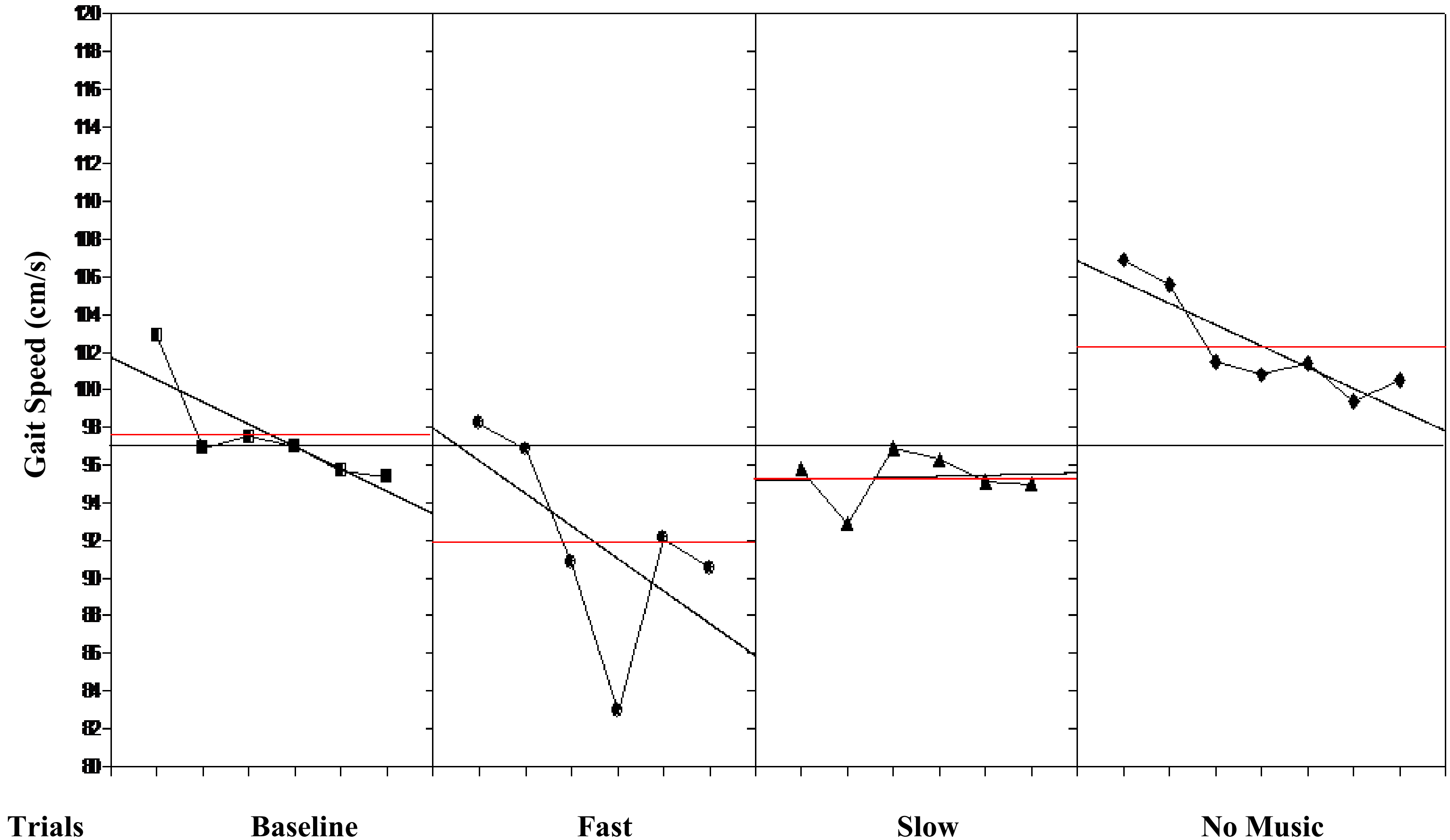

Figure 4.8 (c): Gait speed of Subject H for Session 3. Music conditions were presented in the following order – Slow Music, Fast Music and No Music. Mean level lines and trend lines for each phase are shown. Data points indicate gait speed in individual trials.

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CHAPTER 5 – CONCLUSION

Movement slowing is commonly seen in individuals with FM and there is a definite need to address this issue. Speed targeted movements as a treatment paradigm has been used to counter slowing in individuals with chronic pain. This study provided evidence for the possibility of using music to promote speed targeted movements in individuals with FM. Relevant literature was reviewed and a case was made for the use and study of music to influence movement in FM. Beside studying the influence of music on movement, it was also estimated whether music could alter pain intensity, affect, mood and perceived exertion in these individuals.

A single subject research design was employed and eight subjects participated in the study. Results indicated that 1) four of the eight subjects in the study walked faster with fast music and 2) they walked faster with no increase in pain intensity, pain affect and perceived exertion. It was initially hypothesized that music would improve mood, decrease pain intensity, pain affect and perceived exertion in these individuals. However, this was not a general trend seen in the study. This could be attributed to the short duration of the test. The participants walked in all conditions for three minutes each. It would be interesting to note if similar results are obtained if the participants walked for a longer duration.

The study also provided information on the type of music that could be used to influence walking speed in people with FM. Fast (tempo-140 bpm) and slow (tempo-80 bpm) popular music tracks were used in the study. Provision of music was beneficial as compared to no music with subjects in the study showing a tendency to walk faster when fast music was used.

Additionally, the design of the study helped identify many factors that could have influenced the subjects' responses to music. These included pain intensity, fatigue, fitness levels, subjects' music preferences and prior experiences with music. However, the extent to which these factors influenced the effects of music is unknown and could be studied in future. The debriefing session was an enriching component of the study. It gave an insight to the subjects' experiences with the use of music in the study and also helped explain the results obtained.

Summary

Overall, our results indicate that music may be used as a potential tool to counter movement slowing in individuals with FM. The generalizability of the findings is limited by a small sample size. However, the results may help guide design of future studies in the area. Studies with larger samples are necessary to further validate these results and to demonstrate the effectiveness and potential clinical utility of music in rehabilitation of chronic pain conditions in general and FM in particular. This knowledge will be very helpful since the use of music in therapy is cost-effective and hence can be easily transferred to the clinical settings. Music may also be an effective tool that could be part of a home exercise or self management program.

CHAPTER 6 – REFERENCES

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APPENDICES

A1. Profile of mood states test (short form) – English version

*Directions: Describe **HOW YOU FEEL RIGHT NOW** by checking one space after each of the words listed below:*

Feeling	Not at all	A Little	Moderate	Quite a bit	Extremely
Tense	1	2	3	4	5
Angry	1	2	3	4	5
Worn Out	1	2	3	4	5
Unhappy	1	2	3	4	5
Lively	1	2	3	4	5
Confused	1	2	3	4	5
Peeved	1	2	3	4	5
Sad	1	2	3	4	5
Active	1	2	3	4	5
On Edge	1	2	3	4	5
Grouchy	1	2	3	4	5
Blue	1	2	3	4	5
Energetic	1	2	3	4	5
Hopeless	1	2	3	4	5
Uneasy	1	2	3	4	5
Restless	1	2	3	4	5
Unable to Concentrate	1	2	3	4	5

Feeling	Not at all	A Little	Moderate	Quite a bit	Extremely
Fatigued	1	2	3	4	5
Annoyed	1	2	3	4	5
Discouraged	1	2	3	4	5
Resentful	1	2	3	4	5
Nervous	1	2	3	4	5
Miserable	1	2	3	4	5
Cheerful	1	2	3	4	5
Bitter	1	2	3	4	5
Exhausted	1	2	3	4	5
Anxious	1	2	3	4	5
Helpless	1	2	3	4	5
Weary	1	2	3	4	5
Bewildered	1	2	3	4	5
Furious	1	2	3	4	5
Full of Pep	1	2	3	4	5
Worthless	1	2	3	4	5
Forgetful	1	2	3	4	5
Vigorous	1	2	3	4	5
Uncertain about things	1	2	3	4	5
Bushed	1	2	3	4	5

A2. Profile of mood states test (short form) – French version (Fillion & Gagnon, 1999)

Indications: Décrivez comment vous vous sentez maintenant en cochant une case après chacun des mots ci-dessous:

Sentiment	Pas du Tout	Un Peu	Modéré	Tout un peu	Extrêmement
Tendu-e	1	2	3	4	5
Fâché-e	1	2	3	4	5
Éreinté-e	1	2	3	4	5
Malheureux-se	1	2	3	4	5
Vif-ve	1	2	3	4	5
Confus-e	1	2	3	4	5
Irrité-e	1	2	3	4	5
Triste	1	2	3	4	5
Actif-ve	1	2	3	4	5
Crispé-e	1	2	3	4	5
Grognon-ne	1	2	3	4	5
Mélancolique	1	2	3	4	5
Énergique	1	2	3	4	5
Sans espoir	1	2	3	4	5
Incapable de me concentrer	1	2	3	4	5
Énervé-e	1	2	3	4	5
Mal à l'aise	1	2	3	4	5
Avoir les nerfs à fleur de peau	1	2	3	4	5

Sentiment	Pas du Tout	Un Peu	Modéré	Tout un peu	Extrêmement
Rancunier-ère	1	2	3	4	5
Nerveux-se	1	2	3	4	5
Misérable	1	2	3	4	5
Joyeux-se	1	2	3	4	5
Amer-ère	1	2	3	4	5
Épuisé-e	1	2	3	4	5
Anxieux-se	1	2	3	4	5
Incapable	1	2	3	4	5
Fatigué-e	1	2	3	4	5
Désarçonné-e	1	2	3	4	5
Furieux-se	1	2	3	4	5
Plein-e d'énergie	1	2	3	4	5
Sans valeur	1	2	3	4	5
Vigoureux-se	1	2	3	4	5
Oubliant facilement	1	2	3	4	5
Incertain-e	1	2	3	4	5
À bout	1	2	3	4	5
Découragé-e	1	2	3	4	5
Las-se(Tanné-e)	1	2	3	4	5

FIBROMYALGIA IMPACT QUESTIONNAIRE (FIQ)

Last name: **First name:** **Age :**
Todays date :

Duration of FM symptoms (years) : **Years since diagnosis of FM :**

Directions: For questions 1 through 11, please check the number that best describes how you did overall for the *past week*. If you don't normally do something that is asked, place an 'X'in the 'Not Applicable'box.

Were you able to:	**Always**	**Most**	**Occasionally**	**Never**	**Not Applicable**
1. Do shopping?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
2. Do laundry with a washer and dryer?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
3. Prepare meals?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
4. Wash dishes / cooking utensils by hand?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
5. Vacuum a rug?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
6. Make beds?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
7. Walk several blocks?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
8. Visit friends or relatives?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
9. Do yard work?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
10. Drive a car?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4
11. Climb stairs?	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4

Sub-total scores ***(for internal use only)***

Total score ***(for internal use only)***

12. Of the 7 days in the past week, how many days did you feel good? **Score**

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

13. How many days last week did you miss work, including housework, because of fibromyalgia?
Score

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Directions: For the remaining items, mark the point on the line that best indicates how you felt overall for the past week.

14. When you worked how much did pain or other symptoms of your fibromyalgia interfere with your
ability to do your work, including housework?

No problem with work ______________________________ Great difficulty with work

15. How bad has your pain been?

No pain ______________________________ Very severe pain

16. How tired have you been?

No tiredness ______________________________ Very tired

17. How have you felt when you get up in the morning?

Awoke well rested ______________________________ Awoke very tired

18. How bad has your stiffness been?

No stiffness ______________________________ Very stiff

19. How nervous or anxious have you felt?

Not anxious ______________________________ Very anxious

20. How depressed or blue have you felt?

Not depressed ______________________________ Very depressed

Score

Sub-total

FIQ TOTAL

A4. Fibromyalgia impact questionnaire – French version (Perrot, Dumont, Guillemin, Pouchot, & Coste, 2003)

Indications : Les questions qui suivent ont pour objectif de mesurer les conséquences de votre fibromyalgie sur votre santé. Les réponses que vous fournirez à ce questionnaire nous permettront de mieux connaître l'impact de votre maladie sur votre vie de tous les jours.
Merci de bien vouloir répondre à toutes les questions :

-soit en mettant une croix X dans la case correspondante à la réponse choisie. Si vous ne savez pas très bien comment répondre, choisissez la réponse la plus proche de votre situation.

-soit en indiquant d'un trait l'endroit où vous vous situez entre deux positions extrêmes, comme dans l'exemple ci-dessous :
____________________________|______________________

aucune douleur douleurs très importante

1-Étes-vous capable de :(Veuillez entourer le numéro qui décrit le mieux l'état général dans lequel vous vous trouvez actuellement)

(0)Toujours, (1) La Plupart du temps, (2)De temps en temps, (3)Jamais

-Faire les courses ? (0 1 2 3)

-Faire la lessive en machine ? (0 1 2 3)

-Préparer à manger ? (0 1 2 3)

-Faire la vaisselle à la main ? (0 1 2 3)

-Passer l'aspirateur ? (0 1 2 3)

-Faire les lits ? (0 1 2 3)

-Marcher plusieurs centaines de mètres? (0 1 2 3)

-Aller voir des amis ou la famille ? (0 1 2 3)

-Faire du jardinage ? (0 1 2 3)

-Conduire une voiture? (0 1 2 3)

-Monter les escaliers ? (0 1 2 3)

Au cours des 7 derniers jours,

2. Combien de jours vous-êtes vous senti(e) bien ?

0 1 2 3 4 5 6 7

Si vous n'avez pas d'activité professionnelle, passez à la question 5

3. Combien de jours de travail avez vous manqué à cause de la fibromyalgie ?

0 1 2 3 4 5 6 7

4. Les jours où vous avez travaillé, les douleurs ou d'autres problèmes liés à votre fibromyalgie vous ont-ils gêné (e) dans votre travail ?

aucune gêne **gêne très importante**

Au cours des 7 derniers jours,

5. Avez vous eu des douleurs ?

aucune douleur *douleurs très importantes*

6. Avez-vous été fatigué (e) ?

Pas du tout fatigué (e) *Extrêmement fatigué(e)*

7. Comment vous êtes-vous senti(e) le matin au réveil ?

tout à fait reposé (e) au réveil *extrêmement fatigué (e) au réveil*

8. Vous êtes-vous senti(e) raide ?

Pas du tout raide *Extrêmement raide*

9. Vous êtes-vous senti(e) tendu(e) ou inquiet(e) ?

Pas du tout tendu(e) *Extrêmement tendu(e)*

10. Vous êtes-vous senti(e) déprimé(e) ?

Pas du tout déprimé(e) *Extrêmement déprimé(e)*

A5. List of music tracks used in the study

Slow Music Condition

Song	*Artist*	***Rhythm (bpm)***
Caravan Holiday	The Stereophonics	80
Beautiful	Christina Aguilera	80
Keep the faith	Michael Jackson	80

Fast Music Condition

Song	*Artist*	***Rhythm (bpm)***
Last of the big time drinkers	The Stereophonics	140
Beautiful (dance remix)	Christina Aguilera	140
Beat it	Michael Jackson	140

The music tracks used in the study were referenced from a study by Karageorghis and colleagues (Karageorghis, Jones & Low, 2006).

A6. Questions used in the debriefing session

We would like to learn more about this study from your perspective so that we may improve future studies. Hence please answer these questions to the best of your ability.

1. What did you like the most about this study?

2. What did you like the least about this study?

3. Was there any aspect of the study that made you feel irritated or frustrated? If yes – what aspect of the study made you feel that way? Do you have any suggestions as to how the irritating aspect of the study could be improved?

4. Did you enjoy participating in the study? Please rate your level of enjoyment using the following scale.
   □ Did not enjoy at all □ Enjoyed A Little □ Enjoyed Moderately
   □ Enjoyed a Lot
   Do you have other comments related to enjoyment?

5. Did you find the study interesting? Please rate your response using the following scale.
   □ Not at all interesting □ A Little Interesting □ Moderately Interesting
   □Very Interesting. Please explain.

6. Did you experience any difficulty while participating in the study?

7. Did you enjoy the music used in the study? Please rate your response using the following scale.
   □ Did not enjoy at all □ Enjoyed A Little □ Enjoyed Moderately
   □ Enjoyed a Lot. Please explain.

8. What type of music do you usually listen to?

9. Do you think music influences your mood? Why do you think so? (May suggest using an example to explain)

10. Do you like to dance? What sort of music do you dance to?

11. Do you think music influences how you move? Explain.

12. Would you be willing to participate in a similar experiment in future? If yes, why? If not, is there anything that could be done that would encourage you to participate?