BURGESS, K.E. and SWINTON, P.A. 2012. Do Fitflops™ increase lower limb muscle activity? *Clinical biomechanics* [online], 27(10), pages 1078-1082. Available from: https://doi.org/10.1016/j.clinbiomech.2012.08.011

Do Fitflops™ increase lower limb muscle activity?

BURGESS, K.E. and SWINTON, P.A.

2012

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Abstract

Background: Fitness toning shoes are becoming increasingly popular, they aim to increase muscle activity, raise energy expenditure and improve overall health while wearing them. Yet there is a lack of consensus in the literature regarding their effectiveness. One such shoe on the market is the Fitflop™ designed to activate leg muscles through density shifts in the shoe's sole. The purpose of this study was to investigate the effect of wearing Fitflops™ on the muscle activity of the lower limb.

Methods: Twenty three females (age 20.8 (1.3) years, mass 62.9 (11.9)kg, height 165.4 (5.6)cm) participated in the study. Muscle activity of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus of the participant' right limb were recorded using surface electromyography during participation in three different tasks to simulate daily living activities. These were a) treadmill walking b) stair climbing and c) zigzag walking around cones. The participants completed the tasks barefoot, while wearing Fitflops™ and while wearing regular flip flops so that comparisons between muscle activity in the different shoe conditions could be made.

Findings: The results show that there was no significant difference in the activity of the medial astrocnemius, biceps femoris, rectus femoris and gluteus maximus muscles across all shoe conditions and simulated daily activities ($P > 0.05$).

Interpretation: Based on these results, the use of Fitflops™ is not recommended as a means of increasing muscle activity of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus during activities of daily living in a healthy recreationally active female population.

Introduction

Physical inactivity is the fourth leading risk factor for global mortality (WHO, 2010) and despite the clear links between physical activity and health large proportions of the population engage in low levels of physical activity. There have been many reasons put forward and evidenced as to why individuals obtain low levels of physical activity, these barriers to physical activity include (but are not limited too): lack of time, feeling uncomfortable in a gym environment, dislike of recommended activities, poor social support and interruptions of routine (Williams et al., 2007). Methods to increase the population's physical activity which can avoid or overcome some of these barriers are therefore required.

Consequently, the popularity and number of different 'fitness toning' shoes on the market have increased. The idea being that the shoes enhance the training effect of the activities the individuals are already completing and hence increase overall physical activity levels. This therefore does not require the individual to 'give up' any more time, go into an environment they are not comfortable with, partake in activities they dislike or change their daily or weekly routine. The main premise behind these shoes is the unstable shoe construct, whereby the shoes are designed to simulate an effect comparable to a wobble board in order to activate muscles which would be underutilised when wearing a traditional stable shoe (Landry et al., 2010). Manufacturers suggest that the instability of various fitness toning shoes helps to 'tone' muscles (through increased activity), relieve back and joint pain, increase energy expenditure, improve posture and circulation and improve overall health while wearing them (Porcari et al., 2011). The first of this generation of 'fitness toning' shoes on the market comprised the MBT (Masai Barefoot Technologies) with more recent competitors including Fitflop™, Reebok Easytone and Skechers Shape-ups. Each of the manufacturers uses a variation on producing an unstable environment through the shape and densities of the shoes' sole.

To date, there are mixed reports in the literature regarding the effectiveness of fitness toning shoes to increase muscle activity (Murley et al., 2009). The majority of previous studies have focused on the MBT shoe design and although it has been clearly identified that wearing MBT shoes causes changes in the kinetics and kinematics of quiet standing and gait (Nigg et al., 2006; Romkes et al., 2006; Taniguchi et al., 2012), a concurrent change in muscle activity has not been systematically shown (Murley et al., 2009).

Increases in muscle activity whilst walking in MBT shoes have been reported by Romkes et al. (2006) who showed increased activity of the gastrocnemius medialis and lateralis, vastus medialis and lateralis, and rectus femoris during different sections of the gait cycle when compared to the participants normal 'street shoes'. However, no difference has been reported in the activity of gastrocnemius medialis and lateralis, biceps femoris, vastus medialis and lateralis, rectus femoris gluteus medius and maximus, tibialis anterior, peroneus longus, rectus abdominis and erector spinae when MBT shoes have been compared to a standardised control trainer (Nigg et al., 2006; Porcari et al., 2011; Stöggl et al., 2010).

In addition to research utilising MBT shoes, studies conducted using Skechers Shape-ups and Reebok Easy-tone shoes have shown no increases in the activity of leg and abdominal muscles while walking in these shoes compared to controls (Elkjær et al., 2011; Porcari et al., 2011). To the authors' knowledge, studies concerning the effect of wearing Fitflops™ on muscle activity whilst walking have not been published in peer reviewed publications. Therefore there is a lack of robust information regarding the effects of wearing Fitflops™ on muscle activation.

The principle of how Fitflops™ produce instability is based on 'microwobbleboard technology' whereby the shoe's sole has a high density heel, low density mid section and a mid density forefoot (see Fig. 1).

Unlike the MBT and Sketchers shape-ups (which have a rocker sole design) Fitflops™ have a flat sole and the shoe's traditional style is based on that of a thong style flip flop rather than a training shoe. Walking while wearing flip flop style footwear has been previously shown to affect gait kinetics and kinematics (Shroyer and Weimar, 2010). In the study by Shroyer and Weimar (2010) the participants walked at a self-selected pace across a force platform whilst wearing flip flops and sneakers as a control. Kinetic data was obtained from the force platform and kinematic variables determined from sagittal plane digital video recordings. Wearing flip flops resulted in decreased: stance time, breaking impulse and stride length, and larger peak ankle angle during swing phase and at the beginning of double support compared to sneakers (P b 0.05) (Shroyer and Weimar, 2010). Therefore an unstable shoe based on this design may produce different effects than those based on a trainer style.

Fitflops™ primary market is the female population who will substitute Fitflops™ for their regular everyday shoes. Therefore, in order to enhance the external validity of results regarding the effect of wearing Fitflops™ the experimental design will mimic this situation by assessing muscle activity in a variety of tasks which simulate activities of daily living in a group of females (Kahneman et al., 2004). As the flip flop style of shoe has been previously been shown to affect gait characteristics (Shroyer and Weimar, 2010), a standardised flip flop as well as a barefoot condition will be used as controls. Therefore the overall aim of this study is to compare lower limb muscle activity during activities of daily living between Fitflops™ and flip flop and barefoot control conditions.

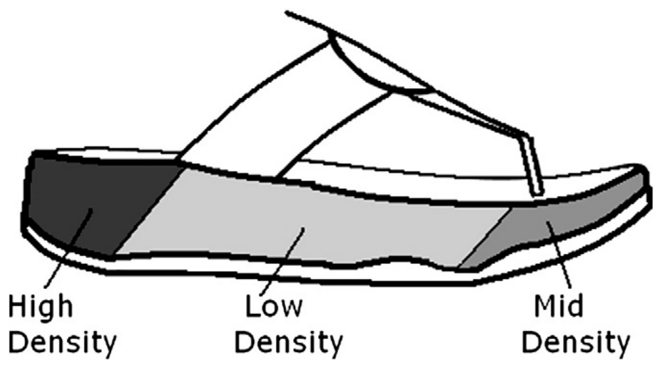

Fig. 1. Diagram to illustrate the shifts in density of the Fitflop™ shoe; the basis of the microwobbleboard technology.

Methods

Participants

Twenty three healthy recreationally active females (age 20.8 (1.3) years, mass 62.9 (11.9)kg, height 165.4 (5.6)cm) volunteered to participate in the study in response to poster and email advertisements. All participants had previously owned and worn flip flop style shoes (within the last 5 years).The investigation was approved by the University Institutional Ethics Committee, and all participants gave their written informed consent to participate in the study. The study is in agreement with the declaration of Helsinki of the World Medical Association.

Study design

The study used a repeated measures design with muscle activity measured during activities to simulate those performed in daily living (treadmill walking, stair climbing and a zigzag walk around cones) in three different shoe conditions (barefoot, Fitflop™ and flip flop). Each participant completed all of the tests on the same day. The order of the footwear condition and stimulated activities were randomised.

Measurement of muscle activity

Pairs of self-adhesive Ag/AgCl electrodes 32 mm x 36 mm (FIAB, Florence, Italy, type F9079P), were placed on clean, shaved, and previously abraded skin, over the muscle belly of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus of the participants right limb. Electrodes were placed in a bipolar configuration with a constant between-electrodes distance of 20 mm centre to centre and positioned inline with Hermens et al. (2000) guidelines. The raw EMG signal was sampled at 2000 Hz, pre-amplified, and filtered using high- and low-pass filters set at 20 and 500 Hz, respectively (Aurion, Zerowire, Italy). All EMG signals were displayed in real time and concurrently saved to computer. Signals were full wave root mean square rectified over 50 ms epochs and the mean rms-EMG for each of the activities was determined using Acknowledge software (Biopac Systems, Inc.). Mean rms-EMG data were normalised using a peak dynamic method (Burden et al., 2003) whereby mean rms-EMG data was expressed as a percentage of the peak rms-EMG during the barefoot treadmill walking trial.

Simulated activities

Three different trials were performed to simulate aspects of daily living, the details of which are outlined below.

Treadmill walking trial

The participants walked at 1.34 ms^{-1} on a flat treadmill (HP Cosmos, Germany) with a 0% gradient. Following 2 min of walking EMG was recorded. Using a pressure pad based voltage input to the EMG recording (Aurion, Zerowire, Italy) the experimenter marked the start and end of 10 walking strides (heel strike to heel strike). This was done three times with 10 strides break in-between. Consequently, the EMG of three lots of 10 walking strides could be analysed (as stated above) and the average of the three trials used for statistical analysis.

Stairs trial

To complete one trial the participants walked up and then immediately down a set of 10 stairs (total height of 6 m). EMG was recorded throughout the trial and 3 trials were conducted by each participant with the average mean-rmsEMG used for analysis. The participants were instructed to walk at their own pace and were not permitted to use the handrails. The time taken for the participants to complete the trials was recorded using a stopwatch.

Cones trial

The participants were required to walk around a series of 5 cones and back again see Fig. 2.

EMG was recorded throughout the trial and 3 trials were conducted by each participant with the average mean-rmsEMG used for analysis. The participants were instructed to walk at their own pace and the time taken for the participants to complete the trials was recorded using a stopwatch. This trial was conducted to stimulate everyday activities which involve changes in direction such as shopping.

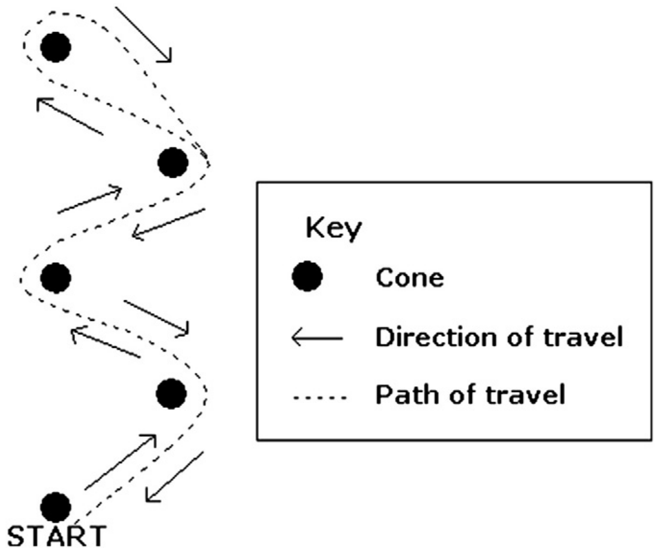

Fig. 2. Cone layout for cones trial. Participants start and finish the trial at the start point. Dotted lines indicate the approximate path of travel and solid arrows the direction of travel.

Shoe conditions

The participants carried out each of the activities designed to simulate those performed in daily living in three different shoe conditions: A) Fitflops™, B) Flip Flops, C) Barefoot, the order of which was randomised (see Fig. 3).

Fig. 3. Footwear used for the two shoe conditions, A) Fitflops™, B) Flip flops.

Statistical analysis

Repeated measures ANOVA's were performed to determine the effect of shoe condition on muscle activity for the 3 activities of daily living and 4 muscles studied. A posteriori power calculations were conducted based on effect size (f) calculated from partial eta^2 (GPower software version 3.1.5). Post-hoc t-tests were performed and P values Bonferroni corrected to examine any differences highlighted by the ANOVA analysis. Significance was set to $P \leq 0.05$. Intraclass correlation coefficients (ICC's) were calculated to estimate reliability of the measures (using data from the repetitions of each activity in each footwear condition). All data are presented as mean with standard error of the mean (SEM).

Results

The within session ICC's for normalised rms-EMG activity ranged from 0.90 to 0.99.

Treadmill walking trial

When walking on the treadmill no significant differences were found in the normalised mean rms-EMG activity of the four studied muscles between the footwear conditions ($P > 0.05$) (Table 1).

Stairs trial

No significant differences were found in the normilised mean rms-EMG activity of the four studied muscles between the three footwear conditions when completing the stairs trial ($P > 0.05$) see Table 1 for values. The stairs trial took on average 10.4 (1.2)s to complete barefoot, 11.2 (2.8)s when wearing Fitflops™ and 11.8 (3.3)s when wearing flip flops; there was no significant difference between these completion times ($P > 0.05$).

Table 1
Normalised mean rms-EMG activity recorded for the four studied muscles in the three footwear conditions during the treadmill walking, stairs and cones trials. Data are mean (SEM).

Trial		Normalised mean rms-EMG (%)			Power
		Barefoot	Fitflop™	Flip flop	
Treadmill walking	Medial gastrocnemius	11.9 (0.8)	11.9 (0.7)	12.3 (1.0)	0.94
	Biceps femoris	15.6 (0.7)	16.9 (1.1)	16.4 (0.9)	0.97
	Gluteus maximus	16.2 (0.8)	17.3 (1.4)	19.4 (1.9)	0.92
	Rectus femoris	18.6 (1.7)	22.1 (2.7)	20.6 (2.1)	0.99
Stairs	Medial gastrocnemius	16.5 (1.9)	15.6 (2.2)	15.9 (1.6)	0.58
	Biceps femoris	17.6 (1.5)	19.4 (2.1)	18.9 (2.3)	0.99
	Gluteus maximus	15.7 (1.9)	15.1 (2.4)	14.4 (2.1)	0.76
	Rectus femoris	20.8 (5.4)	22.2 (5.1)	21.5 (5.2)	0.99
Cones	Medial gastrocnemius	12.5 (1.5)	15.1 (2.0)	13.1 (1.2)	0.96
	Biceps femoris	18.3 (1.1)	19.5 (2.7)	21.1 (3.0)	0.89
	Gluteus maximus	23.4 (4.1)	22.2 (6.5)	22.8 (5.5)	0.78
	Rectus femoris	21.2 (4.3)	22.4 (3.9)	20.5 (4.4)	0.98

Cones trial

No differences were found in the normalised mean rms-EMG activity between the three shoe conditions for the biceps femoris ($P = 0.471$), gluteus maximus ($P =0.899$) or rectus femoris ($P =0.561$) for the cones trial (see Table 1 for values). On the other hand, a significant difference was obtained for the medial gastrocnemius ($P =0.03$). However, when explored using Bonferroni corrected post hoc t-tests the individual between shoe condition comparisons were all non-significant ($P >0.05$). The cones trial took on average 35.4 (6.1)s to complete barefoot, 35.9 (6.3)s when wearing Fitflops™ and 36.1 (5.7)s when wearing flip flops; there was no significant difference between these completion times ($P >0.05$).

Discussion

The purpose of the current study was to investigate the effect of wearing Fitflops^{TM} on the muscle activity of the lower limb by comparing the activity of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus muscles during activities of daily living with control footwear. The results of this study show that wearing Fitflops™ has no effect on the activity of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus muscles during activities to simulate daily living compared to barefoot or regular/standard flip flops.

The results of the current study demonstrate a 7% increase in gluteus maximus activity, an 8% increase in biceps femoris activity and a 0.2% increase in medial gastrocnemius activity when walking in Fitflops^{TM} compared to barefooted ($P > 0.05$). When compared to a control condition of a regular flip flop there was a 10% decrease in gluteus maximus activity, a 3% decrease in medial gastrocnemius activity and a 3% increase in biceps femoris activity when walking in Fitflops^{TM} indicating mixed directional trends ($P > 0.05$). It is important to highlight that although percentage change values for the current study are stated, statistical analysis revealed no significant differences ($P > 0.05$).

Although to the authors knowledge there is no comparable data published regarding Fitflops™ and muscle activity, these findings are in line with the majority of other previous research utilising unstable shoes which has reported no significant difference between muscle activity when walking in unstable shoes compared to a control condition (Elkjær et al., 2011; Nigg et al., 2006; Porcari et al., 2011; Stöggl et al., 2010). However, they do not agree with findings by Romkes et al. (2006) who reported increased gastrocnemius, vastus medialis and lateralis and rectus femoris muscle activity when walking in MBT shoes. In addition to the fact that the unstable shoe used by Romkes et al. (2006) differed from the present study these conflicting results may also be partially explained by the methodology used to analyse the EMG. Romkes et al. (2006) split the gait cycle down into 16 equally time spaced intervals whereas the current study (and other previous studies (Elkjær et al., 2011; Nigg et al., 2006; Porcari et al., 2011; Stöggl et al., 2010) utilised the whole gait cycle. This meant that Romkes et al. (2006) were able to identify sections of the strides during which EMG is increased; however, when this is averaged out over the whole stride this difference is not seen.

Another factor which can influence the muscle activity findings of gait studies is the walking speed (Chiu and Wang, 2007; Hof et al., 2002) unlike most studies (Elkjær et al., 2011; Nigg et al., 2006; Porcari et al., 2011; Stöggl et al., 2010). Romkes et al. (2006) did not control speed in their study and reported significant difference between walking speed between MBT and control conditions ($P = 0.006$). In the current study walking speed was standardised during the treadmill walking trial but not during the cones and stairs trial; however this was monitored and walking speed was shown not to be significantly different between footwear conditions (P b 0.05). It could be argued that if alteration in walking speed is a consequence of wearing unstable footwear then perhaps controlling this limits the external validity of the results.

Some studies also included an instruction and/or an accommodation period prior to muscle activity testing whereby the participants were taught how to walk in the unstable shoes and wore them for a time prior to testing (Nigg et al., 2006; Romkes et al., 2006; Stöggl et al., 2010). Interestingly, only studies which were primarily testing MBT shoes involved this instruction/accommodation period, those which involved Skechers and Reebok shoes did not (Elkjær et al., 2011; Porcari et al., 2011). Although when purchasing MBT shoes individuals do not receive instruction and MBT trainer instruction is available through their website, to the authors' knowledge there is no such instruction provided for the other unstable shoes. It could be argued that this instruction could be an influencing factor on gait and EMG activity and hence it is unclear whether the reported changes are due to the shoe alone or a combination of shoe and instruction. If instruction is required to get the full benefit from wearing the unstable shoes this should be advertised. The current studies results only pertain to the immediate effects of wearing the Fitflop™ unstable shoes without any additional gait instruction.

The applicability of this study's findings is limited to young (18– 25 year old) healthy recreationally active females only. It is possible that although in this population the mircowobbleboard technology in the Fitflop™ doesn't provide a large enough stimulus to make a change, in a less active or older population who possess lower proprioceptive/ balance ability it could have the potential to (Fujiwara et al., 2007). Due to the nature of testing the three shoe conditions it was not possible to blind the participants to the different shoe designs. Therefore individuals had the potential to make conscious or subconscious changes to their walking style because of knowledge of the condition rather than a physiological or biomechanical response to the condition. Although walking speed was monitored and was not significantly different between the shoe conditions other gait kinematics may have been. From the current study it is not possible to determine whether individuals changed their walking style. It is possible that individuals may have been affected differently, for example some individuals may have used ankle stabilisation strategies whereas others knee and hip. Determination of this was out with the aim of the current study but would be worthy of exploration in the future.

In conclusion the results presented here indicate that there are no differences in lower limb muscle activity during simulated activities of daily living between Fitflops™ and flip flop and barefoot control conditions in a healthy recreationally active female population. It is possible that the Fitflops™ did not induce the level of instability required to increase the activity in these larger lower leg muscles, however it is still possible that wearing Fitflops™ could increase activity in smaller stabilising muscles not monitored here, therefore this needs to be investigated. However, it is unclear how this would make any major change to energy expenditure which would have an impact on health. Based on the current study's results the use of Fitflops™ is questioned as a means of increasing muscle activity of the medial gastrocnemius, biceps femoris, rectus femoris and gluteus maximus during activities of daily living in a healthy recreationally active female population.

Conflict of interest

To the authors knowledge there are no conflicts of interest concerning this manuscript.

Acknowledgements

The following individuals should be acknowledged for their assistance with data collection: Yasmine Bazazi, Lauren Braid, Rachel Kidd, Natalie Thomson.

References

Burden, A.M., Trew, M., Baltzopoulos, V., 2003. Normalisation of gait EMGs: a re-examination. J. Electromyogr. Kinesiol. 13 (6), 519-532.

Chiu, M., Wang, M., 2007. The effect of gait speed and gender on perceived exertion, muscle activity, joint motion of lower extremity, ground reaction force and heart rate during normal walking. Gait Posture 25, 385-392.

Elkjær, E.F., Kromann, A., Larsen, B., Andresen, E.L., Jensen, M.K., Veng, P.J., et al., 2011. EMG analysis of level and incline walking in Reebok EasyTone ET Calibrator. 15th NBC on Biomedical Engineering & Medical Physics. IFMBE Proc. 34, 109-112.

Fujiwara, K., Kiyota, T., Maeda, K., Horak, F.B., 2007. Postural control adaptability to floor oscillation in the elderly. J. Physiol. Anthropol. 26, 485-493.

Hermens, H.J., Freriks, B., Disselhorst-Klug, C., Rau, G., 2000. Development of recommendations for SEMG sensors and sensor placement procedures. J. Electromyogr. Kinesiol. 10, 361-374.

Hof, A.L., Elzinga, H., Grimmius, W., Halbertsma, J.P.K., 2002. Speed dependence of averaged EMG profiles in walking. Gait Posture 16, 78-86.

Kahneman, D., Krueger, A., Schkade, D., Schwarz, N., Stone, A., 2004. A survey method for characterizing daily life experience: the day reconstruction method. J. Sci. 306, 1776-1780.

Landry, S.C., Nigg, B.M., Tecante, K.E., 2010. Standing in an unstable shoe increases postural sway and muscle activity of selected smaller extrinsic foot muscles. Gait Posture 32, 215-219.

Murley, G.S., Landorf, K.B., Menz, H.B., Bird, A.R., 2009. Effect of foot posture, foot orthoses and footwear on lower limb muscle activity during walking and running: a systematic review. Gait Posture 29, 172-187.

Nigg, B., Hintzen, S., Ferber, R., 2006. Effect of an unstable shoe construction on lower extremity gait characteristics. Clin. Biomech. 21, 82-88.

Porcari, J.P., Greany, J.F., Tepper, S., Edmonson, B., Foster, C., 2011. The physiologic and electromyographic responses to walking in regular athletic shoes versus "Toning Shoes". Gundersen Lutheran Med. J. 7 (1), 3-8.

Romkes, J., Rudmann, C., Brunner, R., 2006. Changes in gait and EMG when walking with the Masai Barefoot Technique. Clin. Biomech. 21, 75-81.

Shroyer, J.P., Weimar, W.H., 2010. Comparative analysis of human gait while wearing thong-styled slip flops versus sneakers. J Am Podiatr Med Assoc 100 (4), 251-257.

Stöggl, T., Haudum, A., Birklbauer, J., Murrer, M., Müller, E., 2010. Short and long term adaptation of variability during walking using unstable (Mbt) shoes. Clin. Biomech. 25, 816-822.

Taniguchi, M., Tateuchi, H., Takeoka, T., Ichihashi, N., 2012. Kinematic and kinetic characteristics of Masai Barefoot Technology footwear. Gait Posture 35, 567-572.

WHO, 2010. Global recommendations on physical activity for health. . [online] World Health Organisation, Switzerland . Available from: http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf [Accessed 9th April 2012].

Williams, N.H., Hendry, M., France, B., Lewis, R., Wilkinson, C., 2007. Effectiveness of exercise-referral schemes to promote physical activity in adults: systematic review. Br. J. Gen. Pract. 57, 979-986.