Miller, M.D., Daniels, L.A., Bannerman, E., & Crotty, M., 2005. Resting energy expenditure measured longitudinally following hip fracture compared to predictive equations: is an injury adjustment required?. *British Journal of Nutrition*, 94(6), 976-982.

DOI: 10.1079/BJN20051593

British Journal of Nutrition (2005), **94**, 976–982 DOI: 10.1079/BJN20051593

Resting energy expenditure measured longitudinally following hip fracture compared to predictive equations: is an injury adjustment required?

Michelle D. Miller[1], Lynne A. Daniels[1,2], Elaine Bannerman[2] and Maria Crotty[1]*

[1]*Flinders Centre for Clinical Change and Health Care Research, Department of Rehabilitation and Aged Care, Repatriation General Hospital, Daws Road, Daw Park, South Australia, Australia*

[2]*Flinders University Department of Nutrition and Dietetics, FMC Flats, Flinders Drive, Bedford Park, South Australia, Australia*

(Received 10 May 2005 – Revised 14 June 2005 – Accepted 2 August 2005)

The present study measuring resting energy expenditure (REE; kJ/d) longitudinally using indirect calorimetry in six elderly women aged ≥70 years following surgery for hip fracture, describes changes over time (days 10, 42 and 84 post-injury) and compares measured values to those calculated from routinely applied predictive equations. REE was compared to REE predicted using the Harris Benedict and Schofield equations, with and without accounting for the theoretical increase in energy expenditure of 35 % secondary to physiological stress of injury and surgery. Mean (95 % CI) measured REE (kJ/d) was 4704 (4354, 5054), 4090 (3719, 4461) and 4145 (3908, 4382) for days 10, 42 and 84, respectively. A time effect was observed for measured REE, $P=0{\cdot}003$. Without adjusting for stress the mean difference and 95 % limits of agreement for measured and predicted REE (kJ/kg per d) for the Harris Benedict equation were 1 (−9, 12), 10 (2, 18) and 9 (1, 17) for days 10, 42 and 84, respectively. The mean difference and 95 % limits of agreement for measured and predicted REE (kJ/kg per d) for the Schofield equation without adjusting for stress were 8 (−3, 19), 16 (6, 26) and 16 (10, 22) for days 10, 42 and 84, respectively. After adjusting for stress, REE predicted from the Harris Benedict or Schofield equations overestimated measured REE by between 38 and 69 %. Energy expenditure following fracture is poorly understood. Our data suggest REE was relatively elevated early in recovery but declined during the first 6 weeks. Using the Harris Benedict or Schofield equations adjusted for stress may lead to overestimation of REE in the clinical setting. Further work is required to evaluate total energy expenditure before recommendations can be made to alter current practice for calculating theoretical total energy requirements of hip fracture patients.

Energy metabolism: Nutrition: Orthopaedics: Rehabilitation

Hip fractures are a major public health problem with the consequences including impaired mobility and function (Marottoli *et al.* 1992), admission to residential care (Melton, 2003) and premature mortality (Johnell *et al.* 2004) at the individual level and increased burden on finite health resources at the community level (Haentjens *et al.* 2001). By the year 2025 the number of osteoporotic hip fractures is conservatively estimated to increase to 2·6 million world-wide, approximately double the current incidence (Gullberg *et al.* 1997).

Poor nutritional status is a risk factor for osteoporosis (Bonjour *et al.* 2001). Furthermore, protein-energy malnutrition is prevalent (Bastow *et al.* 1983; Patterson *et al.* 1992; Ponzer *et al.* 1999) and has been associated with poorer outcomes amongst older adults who break their hip (Foster *et al.* 1990; Sullivan *et al.* 1990). Nutrition interventions for hip fracture aftercare have been found to have some benefits including reduced length of total hospital stay (Delmi *et al.* 1990), reduced length of stay in rehabilitation (Schurch *et al.* 1998) and reduced complications (Delmi *et al.* 1990; Tkatch *et al.* 1992; Bean *et al.* 1994). A Cochrane systematic review suggested that the overall quality of evidence in this area, however, is still not strong enough to support routine oral nutritional support for hip fracture aftercare (Avenell & Handoll, 2005).

One of the main limitations of studies evaluating the effect of oral nutritional supplements following hip fracture is the lack of attention to the provision of an adequate amount of energy and protein to address the deficits associated with pre-existing malnutrition (Avenell & Handoll, 2005), injury and surgical stress, and inadequate intakes during recovery (Delmi *et al.* 1990; Brown & Seabrook, 1992; Lumbers *et al.* 2001). Energy expenditure in older adults generally and specifically following surgery for hip fracture is poorly understood and estimates of supplement needs are based on limited evidence. Indeed most oral nutritional supplement trials in hip fracture patients prescribe a standard volume based on a convenient number of packs or tins rather than individual nutritional needs (Avenell & Handoll, 2005). Predictive equations such as the Harris Benedict (developed using healthy younger adults; Harris & Benedict, 1919) and Schofield (developed using small samples, *n* 38 women, *n* 50 men, aged >60 years; Schofield, 1985) equations with a factor of 1·35 applied for the stress associated with the injury and surgery (Long *et al.* 1979) are commonly used in the clinical setting (Reeves & Capra, 2003*a*). To calculate total energy expenditure and hence total energy requirements, these values are adjusted further to account for the theoretical cost of physical activity

Abbreviations: MNA, Mini Nutritional Assessment; REE, resting energy expenditure; RGH, Repatriation General Hospital.

* **Corresponding author:** Dr Maria Crotty, fax +61 8 82751130, email maria.crotty@flinders.edu.au

and, if deemed necessary, weight gain (Reeves & Capra, 2003*a*). Whether this method of estimation of total energy requirements is accurate, whether the stress factors applied are necessary and if so, for how long, remains relatively unknown.

There have been four small studies (Jallut *et al.* 1990; Campillo *et al.* 1992; Nelson *et al.* 1995; Paillaud *et al.* 2000) that have reported resting energy expenditure (REE) of hip fracture patients as measured by indirect calorimetry, two of which included longitudinal data. All reported that energy expenditure predicted by equations underestimated measured energy expenditure (range 8–30 %) and recommended that clinicians account for this by increasing the energy density or volume of the intervention. However, it appears that the REE values predicted by the various equations in these studies were not adjusted for physiological stress of surgery and trauma related to the injury, as is commonly recommended (Mahan & Escott-Stump, 2000; Thomas, 2002; Bales & Ritchie, 2004; Todorovic & Micklewright, 2004). Inaccurate estimation of REE potentially leads to provision of inadequate nutritional support with compromised outcomes or excess supplement volume with poor adherence, wastage and undue pressure on this vulnerable group of patients.

The aim of the present study was to measure REE longitudinally in a sample of elderly women following surgery for hip fracture, to describe changes over time and to compare these values to those predicted by routinely applied predictive equations.

Methods

Recruitment of participants

Admissions to the rehabilitation wards at Repatriation General Hospital (RGH) in Southern Adelaide, Australia were monitored between April and November 2003. All females (≥70 years) admitted to RGH within 7 d of hip fracture surgery were potential participants. For inclusion, participants had to reside independently within 20 km of RGH, be medically stable, have no diagnoses of cognitive impairment and not be taking medication affecting energy metabolism. Participants were excluded if they were smokers or had abnormal thyroid function as defined by thyroid stimulating hormone outside of acceptable limits (0·50–4·50 mIU/l). RGH Research and Ethics Committee approved the protocol and all participants provided written informed consent.

Procedures

Measurements were performed on days 10, 42 and 84 following surgery. Day 10 was selected as the earliest possible time for measurement of REE without compromising the rate of recruitment as our previous work had indicated rehabilitation admission was at a median of 10 d. Days 42 and 84 were chosen to coincide with timing of outcome assessments in a randomised controlled trial currently under way in our unit. Whilst on the rehabilitation ward (day 10) participants were measured at the bed-side at 07.00 hours following an overnight fast. Measurements on days 42 and 84 were performed at the RGH trial centre with participants transported from home to arrive by 07.00 hours, again after an overnight fast. Participants were instructed to avoid physical activity on the day before and morning of measurement.

REE was measured by a portable open-circuit calorimeter (GEM; NutrEn Technology Ltd, Cheshire, UK). Participants lay in a supine position and measurement of O_2 consumption and CO_2 production were taken every 30 s for 30 min after 10 min acclimatisation. Standard gases and atmospheric air were used for calibration. The measurement precision of the GEM was verified in three ways. Firstly, calibration values for a sample of eighteen subjects (not involved in the current study) were forwarded to the manufacturer who provided confirmation that the GEM was functioning correctly. Secondly, ten staff and family members were measured in triplicate within 2 h (under the same conditions as the study participants) to enable an assessment of the intra-class correlation coefficient. The intra-class correlation coefficient (two-way mixed model) was 0·98, indicating <2 % measurement error. Finally, monthly whole-system calibration data collected for the duration of the study were assessed. Mean observed RQ was 1·8 % (95%CI 0·8, 2·7) below the theoretical value, a CV of 1·5 %.

Weight for all participants was measured using calibrated digital scales (Seca Mobila 812; Seca Corporation, Columbia, MD, USA) and knee height using a portable sliding knee height caliper (Ross Laboratories, Columbus, OH, USA). Height was estimated using a standard equation (Chumlea *et al.* 1985) and estimated BMI (kg/m^2) was calculated. The Mini Nutritional Assessment (MNA) was administered to all participants on day 10. The MNA is an eighteen-item nutrition screening tool including measurements of anthropometry and questions relating to dietary intake and health (Guigoz *et al.* 1994). The MNA has been reported to be a valid and reliable tool to determine nutritional status in older adults across a variety of care settings (Guigoz *et al.* 1994; Chumlea *et al.* 1999; Bleda *et al.* 2002; Persson *et al.* 2002). A score ≥24 classifies individuals as well nourished, 17–23·5 as at risk of malnutrition and <17 as malnourished (Guigoz *et al.* 1994).

Statistical analyses

Kolmogorov-Smirnov *Z* tests for normality demonstrated data distributions were not significantly different from normal and hence parametric tests were performed. For change in weight, REE and RQ (days 10, 42 and 84), general linear model repeated measures ANOVA were performed (Crowder & Hand, 1990). To determine change for all pair-wise comparisons, *post hoc* Bonferroni correction was applied. Estimated REE was calculated (Harris & Benedict, 1919; Schofield, 1985) and adjusted for physiological stress of injury and surgery (Long *et al.* 1979). To compare measured and predicted REE, the mean difference and 95 % limits of agreement were calculated (Bland & Altman, 1986) and a one-sample *t* test was performed to test whether the mean difference was significantly different to zero. All analyses were conducted using the SPSS for Windows statistical package, version 11.0.0 (SPSS Inc., Chicago, IL, USA).

Results

The median (95 % CI) length of stay in rehabilitation for the participants was 16 (13, 23) d. At day 10 the mean (95 % CI) age of the six participants was 85 (78, 91) years. Mean (95 % CI) estimated BMI at day 10 was 26 (23, 30) kg/m^2 (Table 1). According to the MNA, four participants were classified as well nourished and two at risk of malnutrition (Table 1). Individual and mean (95 % CI) body weight (kg) for each participant is presented in Table 1 for days 10, 42 and 84. Individual and mean (95 % CI) measured REE (kJ/d; kJ/kg per d) for each participant is presented in Table 2 for days 10, 42 and 84. There was a significant

Table 1. Nutritional status of six elderly females (≥70 years) 10, 42 and 84 d following hip fracture*

Subject	Day 10 Weight (kg)	Day 10 BMI (kg/m^2)	Day 10 MNA	Day 42 Weight (kg)	Day 42 BMI (kg/m^2)	Weight change (%), day 10–42†	Day 84 Weight (kg)	Day 84 BMI (kg/m^2)	Weight change (%), day 42–84‡	Weight change (%), day 10–84§
1	55	24	27	52	23	−5	52	23	1	−5
2	79	30	27·5	76	29	−4	78	30	3	−2
3	55	21	23·5	52	20	−6	53	20	2	−4
4	59	26	22	56	25	−6	58	26	4	−2
5	67	28	26	63	26	−6	67	28	6	0
6	74	28	26	71	27	−5	73	28	3	−2
Mean‖	65	26	25	62	25	−5	64	26	3	−3
95 % CI	54, 76	23, 30	23, 28	51, 72	22, 28	−6, −5	52, 75	22, 29	1, 5	−4, −1

MNA, Mini Nutritional Assessment (maximum score 30; score of 24 + indicates well nourished).
* For details of procedures, see p. 977.
† Weight change calculated as: (weight at day 42 − weight at day 10)/weight at day 10 and converted to % by multiplying by 100.
‡ Weight change calculated as: (weight at day 84 − weight at day 42)/weight at day 42 and converted to % by multiplying by 100.
§ Weight change calculated as: (weight at day 84 − weight at day 10)/weight at day 10 and converted to % by multiplying by 100.
‖ See this page for statistical differences.

decrease in measured REE (kJ/d) over time, $P<0·01$ (*post hoc* Bonferroni days 10–42 $P<0·001$, days 42–84 $P>0·05$, days 10–84 $P=0·02$); weight, $P<0·01$ (*post hoc* Bonferroni $P<0·05$ for all pair-wise comparisons); and measured REE (kJ/kg per d), $P=0·02$ (*post hoc* Bonferroni days 10–42 $P<0·01$, days 42–84 $P>0·05$, days 10–84 $P>0·05$).

No change in mean (95 % CI) RQ was observed between the three calorimetric measurements: 0·9 (0·8, 1·0) on day 10, 0·9 (0·8, 1·1) on day 42 and 1·0 (0·9, 1·0) on day 84 ($P>0·05$), indicating that the mixture of fuel oxidised on all three occasions was similar (Table 2).

Without adjusting for stress the mean difference and 95% limits of agreement for measured and predicted REE (kJ/kg per d) for the Harris Benedict equation were 1(-9, 12) day 10, 10 (2, 18) day 42 and 9 (1, 17) day 84. The mean difference and 95% limits of agreement for measured and predicted REE (kJ/kg per d) for the Schofield equation without adjusting for stress were 8 (-3, 19) day 10, 16 (6, 26) day 42 and 16 (10, 22) day 84. After adjusting for stress, REE predicted from the Harris Benedict equation or Schofield equation overestimated measured REE by between 38 and 69%.

Table 3 presents the ratio of predicted REE by measured REE for each participant at days 10, 42 and 84, with and without adjustment for stress of injury and surgery. Without adjusting for stress, REE predicted by the Harris Benedict and Schofield equations overestimated measured REE in the order of 3–15 % and 11–25 %, respectively. Adjusting for stress increased the overestimation of the predictive equations to 38–57 % for Harris Benedict and 50–69 % for Schofield.

Discussion

We found that REE predicted by equations commonly used in the clinical setting overestimated measured REE of elderly females following hip fracture by up to 25 % and that REE decreases between day 10 and day 42 but is comparatively stable from day 42 to day 84. Whilst the present data do not shed light on the precise timing of the catabolic response our data suggest that adjustments to predictions of energy expenditure to account for the physiological stress of injury and surgery may be unnecessary 10 d or more after the injury.

Numerous clinical nutrition texts (Mahan & Escott-Stump, 2000; Thomas, 2002; Bales & Ritchie, 2004; Todorovic & Micklewright, 2004) recommend the Harris Benedict and Schofield equations for estimating the REE of healthy adults. The validity of these recommendations, however, has recently been questioned given the age of the data used in formulating the predictive equations, the small sample size overall and particularly in the older age groups, and the poor predictive value at the individual level (Reeves & Capra, 2003*a*). Studies comparing predicted REE using the Harris Benedict equations with measured REE in

Table 2. Resting energy expenditure (REE; kJ/d; kJ/kg per d) and respiratory quotient (RQ) for six elderly females (≥70 years) 10, 42 and 84 d following hip fracture*

Subject	Day 10 RQ	Day 10 REE (kJ/d)	Day 10 REE (kJ/kg per d)	Day 42 RQ	Day 42 REE (kJ/d)	Day 42 REE (kJ/kg per d)	Day 84 RQ	Day 84 REE (kJ/d)	Day 84 REE (kJ/kg per d)
1	1·0	4250	78	0·8	3620	70	0·9	3885	75
2	0·9	4780	60	0·9	4402	58	0·9	4444	57
3	0·8	4414	80	1·0	3738	72	1·0	4028	76
4	0·9	5183	87	1·0	4498	80	1·0	4175	72
5	0·8	4717	70	0·9	4070	65	0·9	4372	65
6	0·9	4880	66	0·8	4213	59	0·9	3965	54
Mean†	0·9	4704	74	0·9	4090	67	1·0	4145	67
95 % CI	0·8, 1·0	4354, 5054	63, 84	0·8, 1·0	3719, 4461	59, 76	0·9, 1·0	3908, 4382	57, 76

* For details of procedures, see p. 977.
† See this page for statistical differences.

Table 3. Ratio of predicted resting energy expenditure to measured resting energy expenditure (pREE/mREE) for six elderly females (≥70 years) 10, 42 and 84 d following hip fracture*

	Harris and Benedict†			Schofield‡		
Subject	Day 10	Day 42	Day 84	Day 10	Day 42	Day 84
1	0·99	1·13	1·06	1·14	1·30	1·22
	(1·34)	(1·53)	(1·46)	(1·53)	(1·76)	(1·64)
2	1·13	1·19	1·20	1·21	1·28	1·29
	(1·52)	(1·61)	(1·64)	(1·63)	(1·73)	(1·74)
3	1·00	1·15	1·07	1·10	1·27	1·18
	(1·35)	(1·55)	(1·48)	(1·49)	(1·71)	(1·60)
4	0·91	1·02	1·12	0·97	1·09	1·19
	(1·23)	(1·38)	(1·53)	(1·30)	(1·47)	(1·60)
5	1·07	1·20	1·15	1·12	1·27	1·21
	(1·44)	(1·61)	(1·55)	(1·52)	(1·71)	(1·64)
6	1·06	1·20	1·29	1·14	1·29	1·39
	(1·43)	(1·62)	(1·76)	(1·54)	(1·75)	(1·88)
Mean	1·03	1·15	1·15	1·11	1·25	1·25
	(1·38)	(1·55)	(1·57)	(1·50)	(1·69)	(1·68)
95 % CI	0·95, 1·11	1·08, 1·22	1·06, 1·24	1·03, 1·20	1·16, 1·34	1·16, 1·33
	(1·28, 1·49)	(1·45, 1·65)	(1·45, 1·69)	(1·39, 1·62)	(1·57, 1·80)	(1·57, 1·80)

* For details of procedures, see p. 977. Values in parentheses are adjusted for a trauma factor of 1·35 (Long *et al.* 1979).
† pREE predicted using equation proposed by Harris & Benedict (1919).
‡ pREE predicted using equation proposed by Schofield (1985).

healthy adults suggest the equation consistently overestimates energy expenditure by between 5 and 14 % (Daly *et al.* 1985; Owen *et al.* 1986, 1987; Foster *et al.* 1988; Mifflin *et al.* 1990; Case *et al.* 1997). In contrast, the Schofield equation has been shown to both overestimate (McNeil *et al.* 1987; Shah *et al.* 1988) and underestimate (Lawrence *et al.* 1988; Luhrmann & Neuhaeuser, 2004) measured energy expenditure. In addition, it is commonly recommended that estimates of total energy expenditure account for physical activity, physiological stress and required weight gain yet the data to support these correction factors are not well established.

Despite these limitations, the Harris Benedict, Schofield and other similar equations often form the basis for prediction of energy expenditure of acutely ill patients in clinical practice (Reeves & Capra, 2003*b*). In hip fracture patients, four studies have evaluated the difference between REE estimated using predictive equations and measured REE via indirect calorimetry. Three of these studies have reported that the equations significantly underestimate measured REE by between 8 and 20 % (Jallut *et al.* 1990; Nelson *et al.* 1995; Paillaud *et al.* 2000) whilst one study suggests that using the predictive equations of Owen *et al.* (1986, 1987) can either over- or underestimate REE by 30 % (Campillo *et al.* 1992). Direct comparisons between literature findings and the findings of the present study are complicated given the variation in timing of the REE measurement (days 3, 8/9, 21, 51, 81), the range of predictive equations used for comparison (Harris & Benedict, 1919; FAO/WHO/UNU, 1985; Owen *et al.* 1986, 1987) and the lack of detail regarding the use of correction factors to adjust for physiological stress related to injury and surgery (Long *et al.* 1979).

Of the two studies using the Harris Benedict equation for comparison with measured REE (Nelson *et al.* 1995; Paillaud *et al.* 2000), only Paillaud *et al.* (2000) performed measurements longitudinally at similar intervals post-fracture and used an indirect calorimeter that calculates REE using the same equation as that used in the present study (de Weir, 1949). Paillaud *et al.* (2000) reported REE of fifteen hip fracture patients (mean age 86 years) on approximately days 21, 51 and 81 following surgery and found that on average these patients expended at rest 4700, 4500 and 4600 kJ, respectively, approximately 10 % higher than REE measured in the present study on days 42 and 84. Based on the measured values of Paillaud *et al.* (2000), the Harris Benedict equation was found to underestimate measured REE by 9 %, 5 % and 7 % for days 21, 51 and 81, respectively, whilst in the present study the Harris Benedict equation was found to overestimate measured REE by 3 % at day 10 and 15 % at days 42 and 84 post-fracture. Participants in the present study were heavier than those in the Paillaud *et al.* (2000) study (mean 62 kg *v.* 48 kg day 42/51 and 64 kg *v.* 50 kg day 84/81), possibly contributing to the differences observed.

The overestimation is exacerbated if predicted REE is adjusted for physiological stress, as is commonly recommended (Rolandelli & Ullrich, 1994; Reeves & Capra, 2003*b*). In the present study, the adjustment for stress (35 %; Long *et al.* 1979) results in REE predicted by the Harris Benedict equation overestimating measured REE by 38 % at day 10 post-injury (this increasing to over 50 % if considered at days 42 and 84). The hip fracture literature (Jallut *et al.* 1990; Campillo *et al.* 1992; Nelson *et al.* 1995; Paillaud *et al.* 2000) is not explicit in reporting whether the predicted REE includes an adjustment for stress. If we assume not then when REE data predicted by the Harris Benedict equation in the Paillaud *et al.* (2000) study are adjusted for stress, predicted REE overestimates measured REE by 26 %, 30 % and 28 % at days 21, 51 and 81 post-fracture, respectively. This has important implications for clinical practice as overestimating REE, the largest contribution to total energy expenditure, may lead to an unnecessarily high prescription of nutritional supplements, place unrealistic expectations on patients, reduce adherence, increase wastage and in some patients result in overfeeding which may compromise health outcomes (Reeves & Capra, 2003*a*). These implications, however, need to be confirmed by measurement of total energy expenditure. In addition, surplus nutritional supplements may be indicated to prevent weight loss of unknown aetiology early in recovery.

The effect of the bias towards overestimation of REE found in the present study is most evident when considering the findings in relation to the impact on a nutrition support protocol. For example, the Schofield equation estimates unadjusted REE of a 50 kg female (aged >60 years) to be 4655 kJ/d and energy intake of older females following hip fracture is reported as 4200 kJ (Older *et al.* 1980). The shortfall between estimated total energy expenditure and intake is commonly used as the basis for determining volume of nutritional supplement required, in this case an additional 455 kJ/d would need to be met through 110 ml of 1 kcal/ml oral supplement or equivalent to achieve resting requirements, more if REE is adjusted to account for other components of total energy expenditure such as physical activity. According to the findings of the present study, and using the limits of agreement data, REE predicted at day 10 following injury using the unadjusted Schofield equation could be an underestimate of actual REE (by up to 254 kJ/d) or an overestimate of actual REE (by up to 1297 kJ/d). This has implications for clinical decision making and optimal health outcomes given that nutrition support may be deemed either unnecessary or may result in overfeeding (an extra 1297 kJ/d = 310 ml of 1 kcal/ml oral supplement per day = three times the volume using literature estimates). If corrections are made to predicted REE to account for stress then the potential for overfeeding is increased even further, with volumes almost tripling for the same example. It is important to recognise that total energy expenditure was not measured in the present study and that without accurate measurement using techniques such as doubly labelled water, total energy requirements will continue to be calculated using values that may be inappropriate. Adjusting measured and predicted REE in the earlier example to account for physical activity using available theoretical values or prevention of weight loss does not alter the findings described in the example.

It is important to acknowledge that the hip fracture literature and the findings of the present study do suggest there is a catabolic response to stress but of much less magnitude than that proposed by Long *et al.* (1979). Our data also suggest that the catabolic response is resolved some time between days 10 and 42. The data from the Paillaud *et al.* (2000) study, the only other comparable longitudinal study of REE, also suggests that the catabolic response is resolved, possibly by day 21 post-fracture.

It is possible that the stress factors applied in the clinical setting are inaccurate or inappropriately applied. The evidence supporting a 35 % increase in energy expenditure following skeletal trauma was published by Long *et al.* (1979) who measured the energy expenditure of various clinical groups (e.g. elective surgery, skeletal trauma, sepsis, burns) using indirect calorimetry and found that energy expenditure increases correlated with severity of the insult. The patients (n not reported but likely to be <10, mean age not reported) contributing to the data for energy expenditure following skeletal trauma had suffered a motor vehicle or motor cycle accident and had multiple long bone fractures, contusions and lacerations. There were no data presented for patients admitted to hospital for surgical repair of a hip fracture, and therefore adjusting energy expenditure estimated by equations using a factor of 35 % is questionable. Furthermore, the Long *et al.* (1979) stress factors are frequently used with a variety of equations in clinical practice (Reeves & Capra, 2003*b*) although they were only developed by comparing measured REE using indirect calorimetry with predicted REE from the Harris Benedict equation (Long *et al.* 1979).

Strengths of the present study compared to the hip fracture literature include that we measured REE following an overnight fast, our sample consisted of only females, we adjusted our data for body weight and we compared measured REE to REE predicted by equations routinely used by clinicians. Our findings that predicted REE is higher than measured REE and that correction for stress is unfounded, however, should be interpreted with caution. Given the small sample size we may not have an accurate representation of the variability in energy expenditure for this clinical group. Tables 1 and 2 clearly demonstrate the large variability in data, likely contributed to by the small sample size. The small sample size also limits any sub-group analyses, for example evaluating differences in energy expenditure according to surgical procedure or determining differences according to nutritional status. For practical reasons we were unable to measure REE until day 10 and therefore we have no data on the period immediately following the injury and post-surgery. The measurements at days 42 and 84 required participants to travel from home to the trials centre on the morning of the measurement as the indirect calorimeter used was unable to be transported to the participants' home due to its size, weight and fragile componency. The impact of this change in setting on the measurement obtained is likely to have been in the direction of a decrease in REE in the home setting which would have led to a greater change over time and a greater overestimation of REE predicted by commonly applied equations. We are also unable to provide a precise description of when the possible catabolic effect ends as we did not undertake any measurements between days 10 and 42. Future research could overcome these limitations through recruitment occurring in trauma units, more frequent measurements being undertaken and measurement of total energy expenditure by use of doubly labelled water to evaluate the contribution of physical activity to total energy expenditure.

The present preliminary results suggest that measured REE is lower than that calculated using commonly used theoretical equations. Given that REE accounts for a substantial proportion of total energy expenditure, energy requirements calculated using these equations in the clinical setting may be overestimated. This overestimation may be even greater if a multiplier is applied to the calculated REE to theoretically account for a metabolic response to injury and surgery. The present results appear to provide no justification for use of an injury factor in theoretical calculations of energy requirements in hip fracture patients. Physical activity is an important component of total energy expenditure, but the relative contribution to energy requirements attributable to activity during rehabilitation after hip fracture is unknown. Additional longitudinal studies to quantify total energy expenditure and the relative contributions of REE, activity and metabolic responses during the post-operative and rehabilitation recovery phases following hip fracture are required to determine the usefulness of the current theoretical equations to predict individual energy requirements for use in the clinical setting.

Acknowledgements

We thank the research subjects who volunteered to participate in this study. This research was conducted by the first author with support from an NHMRC Public Health Postgraduate Research Scholarship and NHMRC Equipment grant.

References

Avenell A & Handoll HHG (2005) Nutritional supplementation for hip fracture aftercare in older people. *The Cochrane Database of Systematic Reviews 2005,* Issue 2. Art. No.: CD001880. DOI: 10.1002/14651858. CD001880. pub3.

Bales C & Ritchie C (editors) (2004) *Handbook of Clinical Nutrition and Aging*. Totowa, NJ: Humana Press.

Bastow MD, Rawlings J & Allison SP (1983) Undernutrition, hypothermia, and injury in elderly women with fractured femur: an injury response to altered metabolism? *Lancet* **1**, 143–146.

Bean N, Redden J, Goode H, Grimble G & Allison SP (1994) Double-blind pilot trial, in elderly women with fractured femur, of ornithine alpha-ketoglutarate v. a defined formula oral supplement. *Proc Nutr Soc* **53**, 203A.

Bland JM & Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**, 307–310.

Bleda MJ, Bolibar I, Pares R & Salva A (2002) Reliability of the mini nutritional assessment (MNA) in institutionalized elderly people. *J Nutr Health Aging* **6**, 134–137.

Bonjour JP, Ammann P, Chevalley T & Rizzoli R (2001) Protein intake and bone growth. *Can J Appl Physiol* **26**, S153–S166.

Brown KM & Seabrook NA (1992) Nutritional influences on recovery and length of hospital stay in elderly women following femoral fracture. *Proc Nutr Soc* **51**, 132A.

Campillo B, Bories PN, Devanlay M, Pornin B, Le Parco J-C, Gaye-Bareyt E & Fouet P (1992) Aging, energy expenditure and nutritional status: evidence for denutrition-related hypermetabolism. *Ann Nutr Metab* **36**, 265–272.

Case KO, Brahler CJ & Heiss C (1997) Resting energy expenditures in Asian women measured by indirect calorimetry are lower than expenditures calculated from prediction equations. *J Am Diet Assoc* **97**, 1288–1292.

Chumlea WC, Hall G, Lilly F, Siervogel RM & Guo SS (1999) The Mini Nutritional Assessment and body composition in healthy adults. *Nestle Nutr Workshop Ser Clin Perform Program* **1**, 13–22.

Chumlea WC, Roche AF & Steinbaugh ML (1985) Estimating stature from knee height for persons 60 to 90 years of age. *J Am Geriatr Soc* **33**, 116–120.

Crowder MJ & Hand DJ (1990) *The Analysis of Repeated Measures*. London: Chapman and Hall.

Daly JM, Heymsfield SB, Head CA, Harvey LP, Nixon DW & Grossman GD (1985) Human energy requirements: overestimation by widely used prediction equation. *Am J Clin Nutr* **42**, 1170–1174.

de Weir JBV (1949) New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol* **109**, 1–9.

Delmi M, Rapin C-H, Bengoa J-M, Delmas P, Vasey H & Bonjour J-P (1990) Dietary supplementation in elderly patients with fractured neck of the femur. *Lancet* **335**, 1013–1016.

FAO/WHO/UNU (1985) *Energy and Protein Requirements. Technical Report Series no. 724*. Geneva: WHO.

Foster GD, Wadden TA, Mullen JL, *et al.* (1988) Resting energy expenditure, body composition, and excess weight in the obese. *Metabolism: Clin Exp* **37**, 467–472.

Foster MR, Heppenstall RB, Friedenberg ZB & Hozack WJ (1990) A prospective assessment of nutritional status and complications in patients with fractures of the hip. *J Orthop Trauma* **4**, 49–57.

Guigoz Y, Vellas B & Garry PJ (1994) Mini Nutritional Assessment: a practical assessment tool for grading the nutritional state of elderly patients. *Facts Res Gerontol* Suppl. 2, 15–60.

Gullberg B, Johnell O & Kanis JA (1997) World-wide projections for hip fracture. *Osteoporos Int* **7**, 407–413.

Haentjens P, Autier P, Barette M & Boonen S (2001) The economic cost of hip fractures among elderly women. *J Bone Joint Surg (Am)* **83**, 493–506.

Harris JA & Benedict FG (1919) *Biometric Studies of Basal Metabolism in Man*. Washington, DC: Carnegie Institution of Washington.

Jallut D, Tappy L, Kohut M, Bloesch D, Munger R, Schutz Y, Chiolero R, Felber J-P, Livio J-J & Jequier E (1990) Energy balance in elderly patients after surgery for a femoral neck fracture. *JPEN J Parenter Enteral Nutr* **14**, 563–568.

Johnell O, Kanis JA, Oden A, Sernbo I, Redlund-Johnell I, Petterson C, De Laet C & Jonsson B (2004) Mortality after osteoporotic fractures. *Osteoporos Int* **15**, 38–42.

Lawrence M, Thongprasert K & Durnin JVGA (1988) Between-group differences in basal metabolic rates: an analysis of data collected in Scotland, The Gambia and Thailand. *Eur J Clin Nutr* **42**, 877–891.

Long CL, Schaffel N, Geiger JW, Schiller WR & Blakemore WS (1979) Metabolic response to injury and illness: estimation of energy and protein needs from indirect calorimetry and nitrogen balance. *JPEN J Parenter Enteral Nutr* **3**, 452–456.

Luhrmann PM & Neuhaeuser BM (2004) Are the equations published in literature for predicting resting metabolic rate accurate for use in the elderly? *J Nutr Health Aging* **8**, 144–149.

Lumbers M, New SA, Gibson S & Murphy MC (2001) Nutritional status in elderly female hip fracture patients: comparison with an age-matched home living group attending day centres. *Br J Surg* **85**, 733–740.

Mahan LK & Escott-Stump S, (editors) (2000) *Krause's Food, Nutrition, & Diet Therapy*, 10th ed, Philadelphia: W.B. Saunders Company.

McNeil G, Rivers JPW, Payne PR, de Britto JJ & Abel R (1987) Basal metabolic rate of Indian men: no evidence of metabolic adaptation to a low plane of nutrition. *Hum Nutr: Clin Nutr* **41**, 473–483.

Marottoli RA, Berkman LF & Cooney LM (1992) Decline in physical function following hip fracture. *J Am Geriatr Soc* **40**, 861–866.

Melton LJ (2003) Adverse outcomes of osteoporotic fractures in the general population. *J Bone Min Res* **18**, 1139–1141.

Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA & Koh YO (1990) A new predictive equation for resting energy expenditure in healthy individuals. *Am J Clin Nutr* **51**, 241–247.

Nelson KM, Richards EW, Long CL, Martin KR, Geiger JW, Brooks SW, Gandy RE & Blakemore WS (1995) Protein and energy balance following femoral neck fracture in geriatric patients. *Metabolism: Clin Exp* **44**, 59–66.

Older MWJ, Edwards D & Dickerson JWT (1980) A nutrient survey in elderly women with femoral neck fractures. *Br J Surg* **67**, 884–886.

Owen OE, Holup JL, D'Alessio DA, *et al.* (1987) A reappraisal of the calorie requirements of men. *Am J Clin Nutr* **46**, 875–885.

Owen OE, Kavle E, Owen RS, Polansky M, Caprio S, Mozzoli MA, Kendrick ZV, Bushman MC & Boden G (1986) A reappraisal of caloric requirements in healthy women. *Am J Clin Nutr* **44**, 1–9.

Paillaud E, Bories P-N, Le Parco J-C & Campillo B (2000) Nutritional status and energy expenditure in elderly patients with recent hip fracture during a 2-month follow-up. *Br J Nutr* **83**, 97–103.

Patterson BM, Cornell CN, Carbone B, Levine B & Chapman D (1992) Protein depletion and metabolic stress in elderly patients who have a fracture of the hip. *J Bone Joint Surg (Am)* **74A**, 251–260.

Persson MD, Brismar KE, Katzarski KS, Nordenstrom J & Cederholm TE (2002) Nutritional status using mini nutritional assessment and subjective global assessment predict mortality in geriatric patients. *J Am Geriatr Soc* **50**, 1996–2002.

Ponzer S, Tidermark J, Brismar K, Soderqvist A & Cederholm T (1999) Nutritional status, insulin-like growth factor-1 and quality of life in elderly women with hip fractures. *Clin Nutr* **18**, 241–246.

Reeves MM & Capra S (2003*a*) Predicting energy requirements in the clinical setting: are current methods evidence based? *Nutr Rev* **61**, 143–151.

Reeves MM & Capra S (2003*b*) Variation in the application of methods used for predicting energy requirements in acutely ill adult patients: a survey of practice. *Eur J Clin Nutr* **57**, 1530–1535.

Rolandelli RH & Ullrich JR (1994) Nutritional support in the frail elderly surgical patient. *Surg Clin North Am* **74**, 79–92.

Schofield W (1985) Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr: Clin Nutr* **39**, 5–41.

Schurch M-A, Rizzoli R, Slosman D, Vadas L, Vergnaud P & Bonjour J-P (1998) Protein supplements increase serum insulin-like growth factor-I levels and attenuate proximal femur bone loss in patients with hip fracture. A randomized, double-blind, placebo-controlled trial. *Ann Int Med* **128**, 801–809.

Shah M, Miller DS & Geissler CA (1988) Lower metabolic rates of post-obese versus lean women: thermogenesis, basal metabolic rate and genetics. *Eur J Clin Nutr* **42**, 741–752.

Sullivan DH, Patch GA, Walls RC & Lipschitz DA (1990) Impact of nutrition status on morbidity and mortality in a select population of geriatric rehabilitation patients. *Am J Clin Nutr* **51**, 749–758.

Thomas B (editor) (2002) *Manual of Dietetic Practice*, 3rd ed, Oxford: Blackwell Scientific Publications.

Tkatch L, Rapin C-H, Rizzoli R, Slosman D, Nydegger V, Vasey H & Bonjour J-P (1992) Benefits of oral protein supplementation in elderly patients with fracture of the proximal femur. *J Am Coll Nutr* **11**, 519–525.

Todorovic V & Micklewright A (editors) (2004) *A Pocket Guide to Clinical Nutrition*, 3rd ed. Birmingham: PEN Group Publications.