Institution: University of Surrey

Unit of Assessment: UOA 3 Allied Health Professions, Dentistry, Nursing and Pharmacy

Title of case study:

Nutritional interventions for improving the health and performance of the UK military forces

1. Summary of the impact (indicative maximum 100 words)

Within the UK Armed Forces, stress fractures during training in military recruits represent the single largest cause of lost duty days, resulting in substantial costs for the Ministry of Defence.

Research by the University of Surrey has established unique associations between physical characteristics, bone health and nutrition on stress fracture incidence during Royal Marine and Royal Air Force recruit training. This has led the MoD to change entry criteria and to update nutritional advice both in training and during deployment for military personnel. The resultant reduction in number of stress fractures has had both economic and health and wellbeing impacts.

2. Underpinning research (indicative maximum 500 words)

Optimal performance of UK Armed Forces during training and active deployment is of prime importance to the Ministry of Defence (MoD). Stress fractures are responsible for more lost duty days and training recycles than any other training-related injury, costing the MoD £1.34m per year within the Royal Marines alone. The MoD has therefore recognised the importance of developing practices that reduce the risk of such costly injuries, both in terms of health and wellbeing, and economic.

Researchers at Surrey, led by Lanham-New (née New; Professor of Nutrition), have studied extensively the impact of diet on bone health, providing some of the landmark longitudinal and randomised controlled trial (RCT) studies in this area. The Surrey team first demonstrated a positive correlation between dietary nutrients, axial and appendicular bone density, and bone resorption in a Scottish population (**1**). This finding was extended through a 5-year follow up randomised controlled trial in the same cohort, funded jointly by the MRC, DoH and the FSA (**2,3**). The team led by Lanham-New also undertook the first comprehensive longitudinal studies linking sunlight and diet contributions to vitamin D status in younger and older Caucasian and South Asian women (**4-6**), leading to the largest randomised controlled trial comparing vitamin D2 with vitamin D3 efficacy in these population groups (BBSRC DRINC Grant BB/I006192/1).

The importance of bone health and nutritional status to the performance of UK Armed Forces personnel specifically, both in training and during deployment, was initiated in 2006 through funding by the MoD Surgeon General's Office. The Bone Health project examined the relationships between nutritional intake, bone health, stress fracture incidence and training outcomes in 1100 Royal Marine recruits undertaking the 32-week training course at the Commando Training Centre, Exeter, and on 1300 male and female recruits at RAF Halton. In this collaborative project between Surrey and the Institute of Naval Medicine, it was demonstrated that increasing the Royal Marine entry criteria for weight from (60kg to 65kg) and fitness (VO_2 max >51ml.kg-1.min-1, multi-stage fitness test level 11) was associated with a significant reduction in stress fracture incidence. In addition, this study demonstrated that Royal Marine recruits who initiated training in February and March were vitamin D insufficient (serum 25(OH)D <60 nmol/L), which was also associated with a marked increased risk of stress fractures (9.1% vs. 5.9% in

recruits with an acceptable vitamin D status). In addition, Royal Marine recruits who routinely consumed < 1000 mg/d of calcium prior to training, but who were vitamin D sufficient at the start of training, had a 20% chance of stress fracture during training.

These findings were expanded through two further projects funded by the MoD Surgeon General's Office: the Armed Forces Feeding Project (2008), and the Combat Casualty Nutrition Study (2010). Surrey is co-leading these multi-institutional studies to explore the associations between physical characteristics, fitness and nutrition during training, with outcomes of training and the risk of injury.

3. References to the research (indicative maximum of six references)

1. New, S.A., Robins, S.P., Campbell, M.K., Martin, J.C., Bolton-Smith, C., Grubb, D.A., Lee, S.J. and Reid, D.M. (2000) *Dietary influences on bone mass and bone metabolism: further evidence of a positive link between fruit and vegetable consumption and bone health?* American Journal of Clinical Nutrition. 71: 142-151.

2. Macdonald, H.M., New, S.A., Golden, M.H., Campbell, M.K. and Reid, D.M. (2004) *Nutritional associations with bone loss during the menopausal transition: evidence of a beneficial effect of calcium, alcohol, and fruit and vegetable nutrients and of a detrimental effect of fatty acids.* American Journal of Clinical Nutrition. 79:155-65.

3. Macdonald, H.M., Black, A.J., Aucott, L., Duthie, G., Duthie, S., Sandison, R., Hardcastle, A.C., Lanham-New, S.A., Fraser, W.D. and Reid, D.M. (2008) *Effect of potassium citrate supplementation or increased fruit and vegetable intake on bone metabolism in healthy postmenopausal women: a randomized controlled trial.* American Journal of Clinical Nutrition. 88: 465-74.

4. Darling, A.L., Hart,K.H., Gibbs M.A., Gossiel,F., Kantermann,T., Horton,K., Johnsen,S., Berry,J.L., Skene,D.J., Eastell,R., Vieth,R. and Lanham-New S.A. (2013) *Greater seasonal cycling of 25-hydroxyvitamin D is associated with increased parathyroid hormone but not bone resorption*. Osteoporosis International. *in press.*

5. Darling, A.L., Hart,K.H., Macdonald, H.M., Horton,K., Kang'ombe,A.R., Berry,J.L., and Lanham-New S.A*. (*2013) *Vitamin D deficiency in UK South Asian Women of childbearing age: a comparative longitudinal investigation with UK Caucasian women.* Osteoporosis International 24: 477-488.

6. Tripkovic L, Lambert H, Hart K, Smith CP, Bucca G, Penson S, Chope G, Hyppönen E, Berry J, Vieth R, Lanham-New S. (2012) *Comparison of vitamin D2 and vitamin D3 supplementation in raising serum 25-hydroxyvitamin D status: a systematic review and meta-analysis.* American Journal of Clinical Nutrition. 95:1357-64

4. Details of the impact (indicative maximum 750 words)

The incidence of stress fractures can be as high as 8% per year in Royal Marines and 13% per year in female RAF recruits, compared to only 3% in the general population. The Head of the Royal Marine Training Core estimates basic training for a Royal Marine costs £74K for a full training cycle (mean 37 weeks), and with approximately 1,000 Royal Marines being trained every year this equates to an annual bill of nearly £74m.

The typical recovery time from a stress fracture is 10-12 weeks, and thus the estimated cost in lost

time to the military is approximately £1.34m per year within the Royal Marines alone, representing a significant economic impact.

The underpinning research described here was the first body of work to identify the factors associated with increased risk of stress fracture in Royal Marine recruits, and to provide guidelines for mitigation of this risk. In the course of the research, interim reports highlighted the association between nutritional status and health outcomes in recruits (**Ref 1-4**). Such was the strength of this work that it had a significant policy impact, with the MoD changing their entry criteria for recruits immediately following the final report (**Ref 5**): the new entry criteria raised the minimum body mass of recruits from 60 kg to 65 kg and an entry criteria for fitness of VO_2 max >51ml.kg-1.min-1, and multi-stage fitness test level 11 (**Ref 6**), both of which the Surrey research team demonstrated are significant risk factors for in-training stress fractures. In addition to an impact on the entry criteria, this research has led to altered education and advice on nutrition to Royal Marine and RAF recruits, with the aim of optimising performance during training (**Ref 7**).

The research led by the Surrey team has resulted in better selection, more specific physical training, and better quality nutrition (with engaging education) in military recruits. This has resulted in a (conservative) reduction of 2% of stress fractures per year, equating to prevention of some 200 stress fractures. This health and wellbeing impact on the Royal Marine recruits in training also represents a significant economic impact, with savings of at least £0.4M per year.

The impact of this work has extended beyond the recruitment and training of new UK Armed Forces personnel, and also encompasses trained personnel during active deployment. Follow-up studies on military personnel during active deployment in Afghanistan revealed a similar trend for in-combat stress fractures, with poor nutritional status again being a key indicator of risk (**Ref 8**). Based upon this work, the MoD has updated both its Defence Catering Manual and guidelines on Battlefield Nutrition (**Ref 9**), reflecting the need for optimal nutrition for armed forces personnel during deployment.

In addition to direct impacts on MoD recruitment policy, the health and wellbeing of recruits during training, and a reduction in the economic burden of lost duty days and retraining, the studies of the Surrey research team are shaping future MoD research and policy. These research findings, and their resultant impacts, are cited in the Armed Forces Executive Health Report (2013) as landmark case studies on the delivery of improved selection and training guidelines across the three Services, and how this can reduce illness and injury, and increase training success (**Ref 10**).

The Surgeon General's office has recently funded the first-ever vitamin D randomised controlled trial in the British military with stress fracture reduction and susceptibility to infection as the key end points. This 5-year project will commence in spring 2014, and will involve 4,500 Royal Marine recruits (MoDREC 406/MODREC13). This project will be run by the Surrey research team, and will continue to drive the development of MoD policy targeted at improved nutrition for armed forces personnel both during training and active deployment.

In summary, the work of the Surrey research team identified key factors in the risk of both in-training and in-combat stress fractures. As such, it formed the basis for the Ministry of Defence to alter its entrance requirements for new recruits, and alter the nutritional advice given to both new recruits and personnel in combat scenarios. Together these policy impacts have led to secondary impacts on armed forces personnel health and wellbeing, and an economic impact through reduced treatment and retraining costs.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Ref 1. Davey T., Fallowfield J.L., Lanham-New SA.,, Delves S.K. (2008) The relationship of

food provision and nutrient intake to training outcome in Royal Marine recruits: Interim Report I (Start of Training). INM Report 2008.027.

Ref 2. Davey T., Fallowfield J.L., Delves S.K., Lanham-New SA., Layden J. (2008) The relationship of food provision and nutrient intake to training outcome in Royal Marine recruits: Interim Report II (Middle of Training). INM Report 2008.041.

Ref 3. Davey T., Fallowfield J.L., Delves S.K., Lanham-New SA., Layden J. (2008) The relationship of food provision and nutrient intake to training outcome in Royal Marine recruits: Interim Report III (End of Training). INM Report 2008.055.

Ref 4. Fallowfield JL., Cobley R., Dziubak A., Allsopp AJ., Upton H., Lambert H., Lanham-New SA (2009) Surgeon General's Bone Health Project: Broadband Ultrasound Attenuation of the calcaneum in Royal Marine recruits. INM Report 2009.04

Ref 5. Davey T., Allsopp A.J., Delves S.K., Lanham-New S.A., Fallowfield J.L. (2011) The relationship of food provision and nutrient intake to training outcome in Royal Marine recruits: Final Report. INM Report 2011.003 8

Ref 6. Royal Marine – Entrance Requirements (2010) http://c69011.r11.cf3.rackcdn.com/f1ace68faf394e1c80ad1bc758bbace9-0x0.pdf

Ref 7. Fallowfield J.L., Leiper R., Dziubak A., Whittamore D., Lambert H., Osborn A., Lanham-New S.A. (2010) Early Nutritional Habits, Lifestyle Risk Factors and Frequency of injury or illness during Phase-1 Recruit Training at RAF Halton. Final Report. INM Report 2010.001

Ref 8. Fallowfield JL., Delves SK., Cobley R., Nveloa VR., Verral NG., Lanham-New SA., Lambert H., Allsopp AJ. Surgeon General's Armed Forces Feeding Project Operation Feeding in Military Personnel: Final Report. INM Report No. 2010.036

Ref 9. JSP 456: Defence Catering Manual (2011) https://www.gov.uk/government/collections/jsp-315-services-accommodation-code--2#group_491

Ref 10. Ministry of Defence Armed Forces Executive Health Report 2013, MoD, London