

1.0 Introduction

1.1 What is Chromium?

Chromium is a transition metal element, which belongs to Group VI of the periodic table (Expert Group on Vitamins and Minerals (EVM), 2002) and commonly exists in oxidation states 0, +2, +3 and +6. In nutrition, trivalent (+3; III) and hexavalent (+6; VI) chromium are the most important. Trivalent chromium is naturally occurring in air, water, soil and biological material and can be utilised by the human body when present in the diet, whilst hexavalent chromium is man-made, does not naturally occur and is toxic, potentially leading to renal failure, anaemia, haemolysis and liver failure (EVM, 2002). Chromium is of particular interest in nutrition as it has long been suggested as the potentiator (activation) of the anabolic hormone insulin (COMA, 1991) and is suggested that adequate intake of trivalent chromium is required for normal carbohydrate and lipid metabolism.

1.2 Recommended Intake

The adequate intake (AI, used when recommended daily amount (RDA) can not be determined) of chromium in the United Kingdom based on regression equations is $23 \mu\text{g} \cdot \text{d}^{-1}$ set by COMA (1991). A more recent report conducted by Trumbo, Yates, Schlicker and Poos (2001), staff of the Food and Nutrition Board, which provides dietary reference values for Americans and Canadians supported the recommendations of COMA. Trumbo et al. (2001) set the adequate intake of chromium at $35 \mu\text{g}$ and $25 \mu\text{g} \cdot \text{d}^{-1}$ for adult males and females, respectively.

1.3 Sources of Chromium

Foods which are most frequently quoted as high in chromium content are brewer's yeast, meat, raw wheat germ, shellfish and clams (Sharon, 2000). Highly refined foods such as sugar and flour have low chromium content, which is lost during processing. Further, a diet high in sugar is thought to stimulate urinary chromium excretion (COMA, 1991), possibly due to excessive use of the mineral in potentiation of insulin to control glycaemic levels.

1.4 Suggested Role of Chromium

The main manufacturer of chromium picolinate supplements is Nutrition 21 Inc. (Purchase, New York). Nutrition 21, Inc. market their flagship product, Chromax[®], chromium picolinate, as an effective weight loss supplement, which also is able to enhance glycaemic control, increasing lean body mass and reducing body fat mass whilst also maintaining healthy cholesterol, such as HDL-c (Nutrition 21, Inc. 2004). Diachrome[®] is Nutrition 21's product designed for use with Type 2 diabetes patients. Diachrome[®] is a combination of Chromax[®], chromium picolinate and biotin, which is suggested to enhance insulin sensitivity and improve glycaemic control. On the basis of these claims it is not difficult to understand why chromium picolinate supplements are so popular with overweight, obese and diabetic patients. The following two sections are concerned with elucidating the role of chromium in potentiating insulin and the potential benefit chromium supplementation could provide for athletes and the population in general.

1.5 Suggested Role in Metabolism

1.5.1 The Importance of Chromium in Potentiation of Insulin

Vincent (1999) provides evidence to suggest that the biologically active form of chromium is an oligopeptide (short chain of amino acids) called low-molecular-weight chromium-binding substance (LMWCr) now referred to as Chromodulin (Vincent, 2000). Vincent (1999) explains that chromium plays a crucial role in the activation of insulin receptor kinase activity by LMWCr. ApoLMWCr (apo meaning metal/ion free) remains within the cytoplasm of insulin-dependent cells (liver/skeletal tissue) and whilst in this state (apo form) is unable to activate the insulin receptor. Insulin is secreted from the β cells of the pancreas in response to an increase in glycaemic levels (Hames & Hopper, 2000), and binds to the insulin receptors of insulin-dependent cells. This triggers a movement of chromium from the blood into the cell (Vincent, 1999). Ions are removed from the chromium and used to convert apoLMWCr into the active form holoLMWCr (approximately four chromic ions per oligopeptide required for maximal activity). Finally, holoLMWCr is able to bind to the insulin receptor, further activating the receptor kinase activity in a positive feedback manner.

Hames et al. (2000) explain that insulin [with holoLMWCr] binds to the insulin receptor which activates tyrosine kinase, which leads to the activation of an insulin-responsive protein kinase that then phosphorylates [activates] protein phosphatase I. The enzyme, protein phosphatase I, dephosphorylates [activates] glycogen synthase, and phosphorylase kinase is also dephosphorylated [deactivated]. Vincent (1999) explains that when glycaemic

levels return to normal (normoglycaemic levels, 5 mM) insulin levels decrease and holoLMWCr is released from cells to relieve its effects and subsequently excreted in the urine. Hence, high-carbohydrate diets are proposed as a catalyst for depletion of bodily chromium.

1.5.2 The Effects of Insulin on Carbohydrate, Lipid and Protein Metabolism – Potential Changes in Body Composition

Insulin is a powerful anabolic hormone, which influences the metabolism of major dietary substrates, including carbohydrates, lipids and proteins. The suggested function of chromium supplements are as effective “muscle builder” and “fat burners”. This suggestion is made by extending what is already known about the action of insulin in the body. The predominant role of insulin is to regulate blood glucose, by synthesising glucose to glycogen for storage in muscle and liver cells, and inhibiting gluconeogenesis from amino acids and lipids (Campbell & Reece, 2002). Insulin encourages uptake of amino acids and synthesis of proteins. Fatty acids tend to be esterified under the influence of insulin (Frayn, 1991), and are stored in the liver or adipose tissue as triglycerides. Insulin also is a potent activator of lipogenesis, from formation of fat from carbohydrate or protein sources, another mechanism to aid in plasma glucose homeostasis.

1.6 Chromium Depletion and Potential Benefit of Supplementation

The benefits of supplementing diet and training with chromium are many-fold for athletes if chromium is effective at stimulating additional insulin secretion. Potential benefit to strength/power athletes is that additional stimulation of insulin, a powerful anabolic hormone creates the idea of chromium as a muscle builder. Insulin encourages the uptake of amino acids into cells for use in protein synthesis. In the short-term, chromium supplementation could be useful to endurance athletes, combining chromium into a carbohydrate food source so that glucose can be stored and utilised as soon as possible. Individuals undergoing training frequently and consuming a diet high in carbohydrate which may contribute to chromium depletion as suggested by COMA (1991), therefore chromium supplementation may be of greatest value to athletes who train at high volumes, such as elite and international sportsmen and women.

Chromium is also suggested as a potential “fat burner” and is marketed by Nutrition 21, Inc. (2004) as a supplement which can enhance body composition and reduce body mass. The prevalence of overweight and obesity in the United Kingdom was shown to be increasing steadily over the past two-decades in a survey by the Department of Health (2005). In 2004, the Department of Health (2005) reported that 44% of males aged between 16-64 years were classified as overweight and 23% were obese. In the same survey, 35% of females aged 16-64 years were classified as overweight and 24% as obese. Obesity is not limited to the United Kingdom, with many countries across Europe and the developed world displaying high levels of obesity

(World Health Organisation, 2005). Prevalence of overweight and obesity in children in the United Kingdom is also high. A survey by the Department of Health (2005) indicates that 33% and 35% of boys and girls, respectively, aged between 2-15 years are classified as overweight or obese. This is a statistic which suggests that the obesity epidemic will continue long into the next generation.

The World Health Organisation (WHO) (2006) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health. The WHO (2006) estimated that globally in 2005, 1.6 billion adults (+15 years) were overweight, with at least 400 million adults obese. The reasons commonly attributed to the rise in obesity are a shift to a global imbalance between calories consumed against calories expended (WHO, 2006) due to increased intake of energy-dense foods and a decrease in physical activity. The WHO (2006) report that overweight and obesity increase the risk factor of developing chronic diseases, in particular cardiovascular disease (heart disease and stroke) and diabetes (type II). Obesity has also been linked to musculoskeletal disorders, especially osteoarthritis and increased risk of cancer, in particular endothelial, breast and colon.

1.7 Prevalence and Public Usage of Chromium Supplements

A report by the Expert Group on Vitamins and Minerals (EVM) (2000) on the usage of vitamins and minerals in the UK stated mean annual sales of chromium as a single nutrient product during 1998 and 1999 was 410,000 units (one unit equivalent to one tablet/capsule). In relation to other single

nutrient products, chromium was fifth behind sales of calcium, magnesium, boron and zinc. The EVM (2000) indicate that data quoted from the report is representative of at least 70% of the UK market for vitamin and mineral supplements (VMS) sold under food law. Also, this report is unlikely to include the more popular form of the supplement, chromium picolinate, which until December, 2004 was prohibited for sale in the UK and Europe (Patton, 2004).

Patton (2004) reported that the chromium picolinate United States of America (US) market was worth around \$106 million (equivalent to approximately £57 million) in 2003 and was set to rise globally with the removal of restraints on sales of chromium supplements in the European market. Whist Mirasol (2000) reported that the global retail sales of chromium picolinate-containing products totalled nearly \$494 million (equivalent to approximately £307 million) in 2000. As Nutrition 21, Inc. (Purchase, NY) who are the sole patented suppliers of chromium picolinate the report by Mirasol (2000) is related to sales of chromium picolinate predominantly specific to Nutrition 21. Nutrition 21 sells chromium picolinate as Chromax[®], the company's flagship product. Nutrition 21 state "Chromax[®] chromium picolinate is often found as a key ingredient in weight loss and sports nutrition supplements" (Nutrition 21, Inc. 2004). Further, Nutrition 21 market Chromax[®] as a compound capable of reducing hyperglycaemia and stabilising blood glucose, increasing lean body mass and reducing body fat, and for maintaining healthy cholesterol (lipid) levels.