MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Medicine and Medical Sciences (ISSN: 2354-323X) Vol. 4(6) pp. xxx-xxx, June, 2016
Available online http://www.meritresearchjournals.org/mms/index.htm

Review

Can Dietary Calcium Consumption be Beneficial in Body Weight Loss Regimen?

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Abstract.

This study aims to clarify the association between calcium consumption and weight loss. The authors used the PubMed search engine as the primary source of information presented in this article. We reviewed all the available articles that looked into the relationship between calcium consumption and weight loss. It was estimated that a 300-mg increase in daily calcium intake was associated with a three-kilogram decrement in body weight (BW). The effect of higher calcium intake on BW was stronger when initial body fat mass was larger. Two major physiological mechanisms might explain this relationship. First, in cell cultures of human adipocytes, calcium deficiency leads to increases in 1,25(OH)2D levels, which in turn increase lipogenesis and decrease lipolysis. Secondly, during fat binding in the gut, increased calcium intake, and thus concentration, in the intestine induces formation of insoluble fatty and bile acid soaps that are excreted through the feces, thus decreasing the amount of fat available for oxidation and/or storage. In clinical trials, increasing dietary calcium intake by 905–4,000 mg/day increased fecal fat excretion by up to 8.2 g per day. Nevertheless, studies reported a greater reduction in BMI when calcium was derived from dairy products rather than from supplements. Finally, there might be a threshold for calcium intake (800 mg/day) above which no additive beneficial effects exist. The benefits of dietary calcium intake in terms of reduction of body weight have been evident and documented in several types of studies, particularly long-term trials.

Keywords: Calcium, Diet, Milk, Obesity, Weight loss

INTRODUCTION

Obesity Worldwide

Obesity is the excess of body fat, not body weight. Simply, the person becomes obese when calorie input is higher than the calorie output, and then the body stores the extra calories in the form of fat in different regions of the human body. The WHO, (2015) defines obesity as abnormal or excessive fat accumulation that may be a risk component for human being. In the year 2014, the WHO approximated that, more than 1.9 billion adults, 18+ years, were overweight. Of these, more than 600 million (31.6%) suffer from obesity. Overall, approximately 13% of the world's adults (11% of men and 15% of women) were obese.

In 2013, it was estimated that forty-two million of children under the age of 5 were overweight or obese. Overweight and obesity are now on the surge in low- and middle-income countries (WHO, 2015). In developing countries with growing economy, the rate of childhood overweight and obesity has been more than 30% higher than that of western world. In Arab countries, the prevalence is increasing, especially among children. For example, in Saudi Arabia the prevalence among children has recently found to be more than 22% among boys and girls, and the prevalence was higher among girls (Al-Mohaimeed et al., 2012; Al-Mohaimeed et al., 2015a; Al-Muhaimeed et al., 2015b).

Consequences of overweight and obesity

Obesity and overweight are primary risk factors for cardiovascular diseases (mainly stroke and coronary heart disease) which were the leading cause of death in 2012; diabetes mellitus; musculoskeletal disorders; some cancers (especially breast, and colon cancer). Weight problems in children are linked to a higher chance of being obese, premature death and impairment in adulthood. In addition to high risks in the adulthood, obese children may experience a high risk of bone injuries, high blood pressure, early indicators of blood insulin resistance, heart problems like and emotional effects. Overall, obesity and overweight relate to more deaths globally than underweight (WHO, 2015).

Article significance

Initially, we used the PubMed search engine as the main source of information presented in this article. After examining all available review articles and meta-analysis studies that investigated the relationship between calcium consumption (either as dairy foods or supplements) and weight loss, we surprisingly noticed that no single study could show the exact relationship or even whether it is positive or negative. Therefore, we revised all available studies (longitudinal cohort, observational, cross section, clinical trials, case control, and interventional studies) and observed that there is an evident positive correlation between calcium consumption- to some extent - and weight loss. In this article we aim to clarify this correlation between calcium intake and weight loss.

Relationship between calcium and body weight

The role of specific micronutrients and food items in the management of overweight problems has been recognized through the past few decades. One of the significant micronutrients and food items is calcium mineral and milk products (Zemel, 1998; Zemel et al., 2000; Zemel, 2003). Calcium is the major constituent of the bones, and it is likewise an important element needed for blood clots, sensors, transmission sensors and muscle shrinkage, besides being required for hormonal and hormone release (Miller et al., 2001).

After publication the results of first epidemiological study by McCarron twenty six years ago (McCarron, 1984) and the outcomes of study carried out by Zemel, (1998), a possible mechanism to describe the surprising opposite relationship between dietary calcium consumption and weight loss was postulated. Since then, this opposite correlation between calcium consumption and weight loss has been commented in different large communities (Buchowski et al., 2002; Davies et al., 2000; Heaney, 2003; Carruth and Skinner, 2001; Lin et al., 2000; Novotny, 2004; Skinner et al., 2003). In contrast, some studies found no such effects (Atkin and Davies, 2000; Phillips et al., 2003; Shapses et al., 2004).

The relationship between calcium and milk consumption and obesity problems have been analyzed in many different types of studies ranging from longitudinal, cross sectional, randomized clinical trials experimental animals studies as well as cell culture models.

Longitudinal cohort studies

Several epidemiologic longitudinal studies associate obesity occurrence and nutritional calcium consumption. Information from the NHANES III revealed that human body fatty tissue was lower in population with the greatest calcium consumption. It was apparent that there was a diminution in the consequences of obesity with each increasing quartile of calcium consumption. At the maximum quartile of calcium consumption, the expectation of being in the highest BMI quartile was diminished by 85% (Zemel et al., 2000).

Moreover, Heaney et al., (2002) examined results from two cohort studies of females investigated from year 1984 to 1985 and year 1995 to 1997. They noticed that the prevalence of obesity among young females at the 25th percentile of calcium consumption was 15%, whereas the prevalence among females in the group whose calcium consumption was equal to the RDA for calcium was 4%. In the second cohort of middle-age females, a reduction in average in excess body weight was associated with increasing calcium consumption. In another longitudinal study, Loos et al., (2004) reported significant and positive correlation between low calcium consumption and high levels of body fat in both black and white males, and only in white females.

In the Amsterdam study (Boon et al., 2005). The researchers examined whether nutritional calcium consumption is correlated with BMI and the meat of four skinfolds, the researchers followed a group of males and females for 23 years started from 1977 to 2000. Their outcomes showed minor evidences of a nil inverse correlation between calcium consumption and whole body piece.

Observational and Cross sectional studies

A study carried on 1771 healthy, early postmenopausal females revealed a significant inverse trend between BMI and increasing milk consumption. The investigators demonstrated that in early postmenopausal females, a low calcium consumption might increase the risks of osteoporosis, but its opposite impact is balanced out by the elevated BMI reported in females with a low calcium

consumption (Varenna et al., 2007).

Reanalysis of observational studies revealed a reliable inverse effect of higher calcium consumption on either adipose tissues, body weight, or excess body weight. In this merged data set, each increase in calcium consumption by 300-mg/day was associated with a decrease in body weight by 1kg and 2.5 to 3kg among children and adults, respectively (Heaney, 2003).

In prospective study, Skinner et al., (2003) noticed ~~a~~ an adverse association between calcium consumption and percent of body fat in a group composed of 8-year-old children. In that study, it calculated that children could lose 0.4% of their body fat by consuming an additional 240 ml of skimmed milk or 240 ml of low-fat milk. Results of the Quebec North America Family Study (Drapeau et al., 2004) showed that calcium and milk products consumption triggered positive changes in whole body composition.

Clinical Trials, Case Control, and Interventional Studies

Human model

A randomized clinical trial carried out on 259 overweight diabetic adults (mean BMI 31 kg/m^2) to find out the effect of calcium consumption from milk sources on body weight, cardiovascular diseases (CVD), and diabetes biomarkers. The study continued for six months and investigated the impact of three isocaloric meals in patients suffering from T2DM: the first was mixed glycemic index carbohydrate meal, the second was low–glycemic index meal, and the third was modified Mediterranean meal. Low-fat milk product consumption was diverse within and between the groups by personal choice. The results indicated that calcium from milk was linked with a little percentage of weightloss. The researchers postulated that eating meals rich in calcium from milk sources enhances weightloss in Type 2 diabetes patients (Shahar et al., 2007).

In a research carried out to evaluate the correlation between calcium consumption and serum vitamin D with weight-loss, data were collected from 322 adult respondents in the 2-year- Dietary Intervention Randomized Controlled Trial (DIRECT) (BMI 31 kg/m^2, mean age 55 yr). The results of the research indicated that both higher calcium consumption from milk and elevated serum vitamin D are correlated to higher diet-induced weight-loss (Shahar et al., 2010).

A research carried out on adolescents (25 girls and 17 boys; BMI 33 kg/m^2 and 28 kg/m^2 respectively), taking part in two a three-week managed feeding sessions. In the first session, 756 mg calcium per day was applied; in the second session, additional 650 mg calcium daily was offered as milk or calcium mineral carbonate tablets. Total calories and micronutrient consumption were managed and were the same for the two sessions. The results revealed no impacts of the amounts or sources of calcium mineral on fat and calorie balance. The information obtained from this research offers little proof to sustain the speculated mechanisms for the correlation between an increase in calcium consumption from supplements or milk and weightloss or maintaining body weight among adolescents (Weaver et al., 2011).

A randomized clinical trial for 21-week (Palacios et al., 2011) was carried out on 30 obese adults living in Puerto Rica (age 21–50 year), with regular calcium consumed <700 mg/day. Respondents were randomly assigned to the following groups: high milk (~1300 mg/day of calcium mineral from milk by replacing foods); high calcium mineral (~1300 mg/d of calcium; ~700 mg/d from food and 600 mg/d from a supplement); or placebo. Respondents were ordered to keep their traditional dietary consumption (except for the high milk group) and their exercising throughout the research period. The researcher found no significant group impacts in any of the measured outcomes and concluded that high milk or calcium diet alone did not change body composition or blood lipids profile. However, we think that the baseline low calcium intake of the selected sample (<700 mg calcium/day) may be an apparent limitation of the study, where the subjects may use the calcium for improving calcium hemostasis without affecting body fat.

Research carried out on 49 participants to find out whether nutritional pattern rich in milk and calcium enhances weight-loss and very subjective hunger to a higher degree than a low milk/ calcium diet throughout calorie restriction in obese and overweight adults who suffering from metabolic syndrome. Respondents were randomly allocated to the following treatment groups: control (low milk, <700 mg/day calcium, and 500 kcal /day) or milk/ calcium (high milk, >1400 mg/day calcium and 500 kcal/day) for 12 weeks. The results showed that the percent of predicted weight-loss obtained was higher among the high milk/calcium (82.1±19.4%) than the control group (32.2±7.7% and $P<0.05$). In addition, participants in the milk/ calcium group experienced satisfying ($P<0.01$), and had lower dietary fat ingestion ($P<0.05$) over 12 weeks in comparison to control (Jones et al., 2013).

Animal model

Outcomes of studies in animals showed that high-calcium meals caused a 51% decrement in adipocyte fatty acid synthase appearance and activity and a 3- to 5-fold increase in fat catabolism (Zemel, 2003). Low-calcium meals prohibited weight-loss in animals exposed to energy restriction, whilst high-calcium meals increased body fat loss (Zemel, 2003).

Threshold for calcium intake

Boon et al. (2005) found no variations between the middle (800–1.200 mg/day) and high (>1.200 mg/day) groups of calcium consumption, indicating a limit of around 800 mg/day above which increased calcium consumption has no more advantages impacts on body composition.

In adults an increase in calcium consumption of 900 mg/day as supplements or increasing milk consumption to three cups per day (about 1300 milligram of calcium/day) was not an effective strategy for weight-loss. There is, nevertheless, evidence that about three cups/ day of milk products may accomplish body fat loss when consuming weight-loss diet for a short time (Booth et al., 2015).

Mechanism of action

The possible mechanisms involving calcium that might favor weight loss are still not fully interpreted. However, in that respect there are three potentials mechanisms that might elucidate the effect of calcium.

Effect of Dietary Calcium on Adipocytes

About 99% of body calcium is in the extracellular space, and most of extracellular calcium is in teeth and bones. The rest of the 1% of calcium mineral is in the intracellular space. However, the intracellular calcium facilitates several metabolic routes, including platelet aggregation and insulin resistance (Schrager, 2005). Calcitropic hormones (PTH and calcittriol), regulate intracellular calcium. The results of in vitro and in vivo studies postulate that low dietary calcium consumption promotes high level of PTH and calcittriol, which in turn activate high concentrations of intracellular calcium mineral in adipose tissues promote fat formation and inhibits fat breakdown, increasing body fat and causing insulin resistance. High nutritional calcium consumption inhibits the levels of PTH and calcittriol, thereby causing 'abnormal' amounts of intracellular calcium and suppressing fat formation and promoting fat breakdown (Zemel et al., 2000; Zemel, 2003; Zemel, 2002). Therefore, calcium consumption might cause an effect on adipocytes store or break down fat.

Change in Fat Absorption

Some other potential mechanism is the interaction between calcium and body fat in the stomach, that lead to promoting the formation of complex insoluble calcium–fatty acid compounds, which in turn increase fecal fat removal, decreases dietary calories, (Jacobsen et al., 2005) and thereby inhibiting fat absorption (Schrager, 2005). Calcium supplementations have been shown to increase the portion of removal of total fat as correlated to fat consumption (Welberg et al., 1994). Moreover, Denke et al., (1993) observed that calcium supplements (2 g/day) increased daily percent of fat eliminated from 6% to 13%.

Gut microbiota

The benefits of calcium consumption may be correlated with abdominal microbiota modulation and with increased integrity of the gut mucosa, as the data obtained from human and animal studies indicated that these gut factors play a significant role on being overweight and diabetic (Larsen et al., 2010). Gut microbiota comprises key point that impacts nutrient absorption, calories homeostasis, body weight management and blood insulin (Frazier et al., 2011). According to Gomes et al., (2015) dietary calcium appears to favorably affect the gut microbiota composition, which may limit obesity. The mechanisms suggested involvement of bile acids and fatty acid precipitation and, therefore, a loss of luminal cytotoxicity, lacto- bacilli over growth and reduction of damage in gut mucosa. Calcium seems to enhance digestive tract integrity to a high level, whilst the amount of phosphate in the meal or the source of the calcium supplements seems to have little or no effects.

Nutrients or foods that may enhance or inhibit calcium effects

Yoghurt

Globally, yoghurt is a common element of the food consumption pattern of individuals, and regular daily intake is associated with reduction in BMI, waist circumference, body weight/weight gain, and human body fat in epidemiological studies. Randomized controlled trials indicate that yogurt have weightloss effects. Well-planned, effectively powered tests in research and community setting seem to identify a moderate, but the valuable effect of yoghurt intake for protection against excess body weight gain and obesity management (Eales et al., 2015). In addition, evidence of non-bias randomized controlled trials proved that yoghurt consumption over 12 weeks significantly reduced the quantity of body fat among overweight/obese individuals compared to a no yoghurt intake group when maintained on a low energy diet (Zemel et al., 2005).

However, we think that well designed and executed, randomized controlled trials with adequate subjects are required to get a better elucidation of the potential mechanism of action and the possible cause-effect association between yogurt and body weight.

Vitamin D

Human obtain Vitamin D from sun exposure, from foods, fortified foods, and accessories. Vitamin D enhances calcium absorption into the blood vessels. Status of vitamin D is consistently negatively correlated with BMI (Major et al., 2007; Ortega et al., 2008).

In the Women's Health Initiative Study, females who randomly designated to the calcium and vitamin D supplement group had significantly less excess body weight (Caan et al., 2007). Another intervention study of supplements with calcium and vitamin D in 63 overweight or obese females resulted in improvement and beneficial force on body weight-loss and blood lipid profile (Major et al., 2007). Shahar et al., (2010) noticed that both higher dietary milk calcium consumption and elevated serum vitamin D were separately correlated with weight-loss. Moreover, Shahar et al., (2010) observed an elevation in serum 1,25 (OH) D among subjects who loss higher weight.

An intervention study conducted by Shahar et al., (2010) on 322 respondents in the 2-year DIRECT found that after adjusting for age, sex, BMI, and total fat consumption, greater six-month trial levels of milk calcium consumption and serum 25 (OH) D were associated with higher weight-loss across the 2-y intervention. After adjustment for age, gender, BMI, total fat consumption, vitamin D level, and milk calcium for multivariate logistic regression, the same researchers noticed an increase of 1 SD in milk calcium consumption increased the possibility of weight-loss of 4.5 kg, and they recommended that both greater milk calcium consumption and elevated serum vitamin D are correlated with greater diet- caused weightloss.

In 16-week double-blind, placebo-controlled trial was carried out on 171 participants by either regular or reduced-calories freshly orange juice. The intervention groups consumed three glasses (240-mL) of fresh orange juice prepared with 350 mg calcium and 100 IU vitamin D per cup. After 16 weeks off the intervention, the impact of calcium and vitamin D on visceral adipose tissues (VAT) was extremely significant; the results of this research speculated that calcium mineral and/or vitamin D supplements contribute to an advantageous decrease of VAT (Jennifer et al., 2012).

A clinical study carried out on 53 healthy, overweight and obese university students with very low calcium mineral consumption. The researchers examined the impact of calcium plus vitamin D3 supplements on body dimensions and metabolic profiles during calorie restriction. The researchers observed a higher and significant reduction in body fat mass loss, visceral fat mass and visceral fat area in the calcium and vitamin D group. The results of this research showed that calcium plus vitamin D3 supplements for 3 months enhanced body fat and visceral fat reduction in very-low calcium consumers during calorie restriction (Zhu et al., 2013).

One potential explanation of the negative association between vitamin D and body weight is a causal relationship by which greater vitamin D levels enhance metabolic routes favoring body weight loss or improved muscle (Teegarden et al., 2008). In addition, researchers noted an increase in the thermic effects of food and an inclination toward increased fat turnover in overweight women with greater 25 (OH) D levels (Teegarden, 1998).

In conclusion, results from several researches recommend that both higher intakes of milk calcium and elevated serum vitamin D separately correlate with successful weight loss. However, we consider that the route and causality of this correlation still is unclear and needs further explanation.

Proteins

High protein diet creates a lot of acid in body fluids, and the renal system responds to this dietary acid challenge with net acid removal and, simultaneously, the bones supplies base buffer by active resorption of bone causing in excessive calcium loss (Barzel and Massey, 1998). Moreover, increasing acid prevents kidney calcium absorption and thereby leading to hypercalciuria (Goldfarb, 1988; Goldfarb and Coe, 1999). In an Interventional metabolic study, the researchers found a rise in protein consumption from 47 to 112 g/day led to a cost elevation in urinary calcium and a decrease in calcium preservation. Their results showed that the protein-induced hypercalciuria may be due to an increase in GFR and a lower fractional kidney tubular reabsorption of calcium. Another research on respondents consuming diets containing 48 g protein to 142 g per day revealed that urinary calcium more than doubled, whereas the calcium balance became negative (Kim and Linkswiler, 1979).

Regarding animal and plant proteins, a cohort study in postmenopausal females revealed that a high rate of animal to plant proteins elevated the rate of calcium loss and the risk of fractures. The researchers postulated that animal protein containing-foods provide primarily acidity precursors, whereas plant proteins containing-foods are ~~is~~ balanced by alkaline precursors not occurring in animal sources. Furthermore, the discrepancy between nutritional acidity and alkaline precursors leads to a chronic net nutritional acidity load that might have negative effects on bone health. An increase in plant protein consumption and a decrease in protein consumption may increase calcium retention (Sellmeyer et al., 2001; Delimaris, 2013). Results of the study by Josse et al., (2011) indicate that exercise and diet caused weightloss with higher proteins and increased milk product consumption encourages body weight changes in females.

Recent reports have highlighted that an increase in protein consumption could be favorable, especially for

obese and overweight persons who attempt to lose body weight, and for physically active individuals (Westerterp-Plantenga et al., 2009; Wycherley et al., 2012; Moore et al., 2014; Murphy et al., 2015; Phillips, 2014). Nevertheless, consuming diets high in proteins also spare muscles and free body fat mass during weight-loss (Wycherley et al., 2012; Moore et al., 2014; Murphy et al., 2015; Phillips, 2014; Pasiakos, 2015). In addition, available evidence speculates that high protein diets might enhance glycemic control and intestinal calcium absorption (Pasiakos, 2015; Smith et al., 2011).

The extent to which high protein meals are valuable is mostly related to the capacity of the gut absorptive functions, and also to the content of essential amino acids (EAA) of the protein. Proteins that are quickly digested and absorbed, this could possibly be a factor in the metabolic benefits presented by consuming diets rich in protein. The lines of evidence established that the EAA content, and gut absorptive properties of milk protein are particularly valuable (Pasiakos, 2015).

Dietary calcium vs. supplements

Numerous studies have proposed that the source of calcium mineral (milk products vs. Supplements) could affect the consequences on body weight and body fat mass. Studies on rodents (Zemel et al., 2000) and on obese adults (Zemel et al., 2004) showed that milk have greater impacts on decreasing body weight and body fat mass than the same level of calcium from supplements. We agreed with Shah (Shah, 2000) that milk and milk products are rich in bioactive substances, which might explain some of these favorable effects.

Zemel et al., (2004) in their intervention study of obese individuals who were fed low calorie diet for 24 weeks, revealed that high calcium diets either from milk (1137 ± 164 mg/d of calcium) or calcium supplements (1256 ± 134 mg/d of calcium) considerably reduced body weight and body fat mass when compared to the control group (430 ± 94 mg/d of calcium).

Various clinical trials compared the effect of calcium, from either milk or supplements on weight-loss. One study carried out on 340 obese women could not obtain a significant reduction either in body weight or body fat mass, while on ingestion of calcium supplements to their regular diet for two years (Yanovski et al., 2009).

In a very recent meta analysis (Booth et al., 2015), of randomized controlled study in which they assessed the impact of calcium, either supplements or as milk, on body weight and the human whole body composition, the researchers found that calcium supplements could not significantly affect either body weight or body fat mass in comparison to control. In addition, they found similar findings in milk calcium, where they mentioned that increased milk consumption could not change body weight or body fat mass in comparison to the controls.

However, their sub-analyses revealed that milk supplements in the presence of calorie restriction for four months have no change in body weight, but a greater reduction in body fat mass in comparison to controls.

From our findings, in humans, calcium from milk products exerted considerably higher anti-obesity effects than did calcium from supplements, and this may be in part due to high content of bioactive substances in milk and milk products (Caan et al., 2007; Teegarden, 1998; Van der Meer et al., 1990). Milk proteins contain considerable angiotensin-converting compound (ACE) inhibitor activity (Shi et al., 2001a; Shi et al., 2001b). Available information showed that adipocyte fat synthesis is controlled, in part, by angiotensin II and that adipocytes have an intact paracrine/autocrine rennin-angiotensin system (Torres and Sanjuliani, 2013). Furthermore, ACE inhibition slightly attenuates weight gain in animals. Therefore, milk-based ACE inhibition might partly explain the considerably greater effect observed in milk calcium than by non-milk calcium on the amount of weight-loss.

Side effects of calcium overconsumption

Except for apparent problems directly related to calcium e.g. calcium stones, the studies did not reveal any side effects of overconsumption of dietary calcium. However, we recommend not exceeded the recommended amounts according to age and sex. In one randomized intervention study carried out on thirty five obese persons they were found to have lost at least 3% of their body weight over a period of 16 weeks of caloric restriction (800 Kcal/d). The study participants were randomly classified according to dietary calcium into two subgroups: (1) a high calcium group (1200–1300 mg/d) or (2) a low-calcium group (500 mg/d). The results of this study emphasize that increased calcium consumption during the weight-loss session has no effects with regard to biomarkers of inflammation, fibrinolysis, and endothelial function (Torres and Sanjuliani, 2013).

SUMMARY AND CONCLUSIONS

In conclusion, the benefits of dietary calcium intakes in reduction of body weight are clearly evident and well documented in several types of studies, especially in long term trials. In addition we postulate that dietary energy restriction or exercise is mandatory, where most of the interventional studies which proved the correlation between calcium and weight loss were based on restricted diets. Moreover, protein and vitamin D help

calcium in reducing body weight. There is no doubt that milk may contain other active compounds that may help in weight loss. Finally, we think the observation that calcium did not change body weight among obese children may be due to the fact that their bodies are using calcium for growth. There is no need to increase calcium intake above recommended amounts or take supplements.

ACKNOWLEDGEMENT

We would like to convey our deep thanks to senior students in Clinical Nutrition Dept. University of Dammam, KSA for their valuable service through providing some valuable published articles.

Author Disclosers

The authors have no financial disclosures or conflicts of interest to declare and the article was written independently.

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