Research Article

International Journal of Cardiology and Cardiovascular Disorder

Link Between Daily Sunlight Exposure and Dyslipidemia Patients – A Cross-Sectional Study

Gunasekaran Ramanathan

Departments of Physiology, Swamy Vivekananda Medical College Hospital and Research Institute (SVMCH-RI), Elayampalayam, India- 637205, Affiliated to MGR Medical University, Chennai, India.

*Corresponding Author

Prof. Dr. Gunasekaran Ramanathan,
Departments of Physiology, Swamy Vivekananda Medical College Hospital and Research Institute (SVMCH-RI), Elayampalayam, India- 637205, Affiliated to MGR Medical University, Chennai, India.

Submitted : 26 Feb 2024 ; Published : 12 Apr 2024

Citation: Ramanathan, G(2024). Link Between Daily Sunlight Exposure and Dyslipidemia Patients – A Cross-Sectional Study. I J cardio & card diso; 5(2):1-9.

Abstract

Background: *Earlier studies have suggested that Sunlight and vitamin D are related to cardiovascular disease (CVD), but the link between sunlight exposure and risk factors for CVD has not been adequately investigated. Dyslipidaemia is a major risk factor for CVD we aim to investigate whether sunlight exposure has an effect on dyslipidemia patients' serum lipid profile and vitamin D.*

Methods: *This study was carried out in apparently healthy Indian adults of both sexes, aged above 18 years and dyslipidemia patients' from Swamy Vivekananda Medical College Hospital (SVMCH). Normal control group (healthy subjects) (n30), Dull sunlight exposure group dyslipidemia patients N30, and bright sunlight exposure group dyslipidemia patients n30, Oral supplement of Vitamin D group (n30), Obese dyslipidemia patients group (n30) before and after sunlight exposure, after overnight fasting peripheral venous blood samples were collected, and the serum was stored in -80 ^{o}C fridge. Serum levels of 25(OH) D (25- hydroxy vitamin D3) and lipid levels were analyzed by routine lab method using an Autoanalyzer.*

Results: *We compare the bright and dull sunlight exposure dyslipidemia patients and obese groups; a significant elevation was seen in 25-(OH) D concentrations in the bright sunlight exposure group ($P < 0.01$), and the lipid profiles TGs, TCs, LDL-C, and VLDL-C were significantly decreased ($P < 0.05$). The HDL-C level significantly increased when compared to the dull sunlight exposure group. There was no significant change in serum Vitamin D and lipid profile level of the oral supplement vitamin D group compared with the bright sunlight exposure group.*

Conclusion: *Our study reveals that bright sunlight exposure is beneficial and linked with the improvement of Vitamin D and lipid profile of dyslipidemia. In comparison orally supplemented Vitamin D had an adverse effect on lipid profile.*

Keywords: 25-(OH) D, LDL-C, dyslipidemia, Sunlight exposure, lipid profile

Introduction

Cardiovascular disease (CVD) and cerebrovascular diseases are the leading cause of mortality in the world. (Go et al., 2013; Yang et al., 2012). Dyslipidemia is a primary and prominent risk factor for CVD and cerebrovascular diseases (Yusuf et al., 2004). The early abnormalities of lipids, and lipoproteins are independent predictors of Coronary artery diseases (CAD) and CVD (Gordon et al., 1989; Sarwar et al., 2007; Bansal et al., 2007).

Depending on the weather, cardiovascular health varies (Wang et al., 2016) various environmental factors can efficiently increase the risk for hypertension dyslipidemia, metabolic syndrome, and other diseases (Subramaniam, 2007; Halonen et al., 2011). The potential link between temperature variations and serum lipid profile has rarely been investigated (Yamamoto et al., 2003; Neild et al., 1994), particularly seasonal temperature variation and sunlight exposure have not been investigated adequately.

An earlier study reported that sunlight exposure and Vitamin D are related to CVD (Wortsman et al., 2000; Dobnig et al., 2008). However, the link between sunlight and the risk factors is not adequately investigated. Decreased serum Vitamin D level because of increased triglyceride (TG) (Martini et al., 2006; Polkowska et al., 2015) further, decreased Vitamin D levels induces CVD (Giovannucci et al., 2008; Wang et al., 2008), hypertension, organ cancer (Lappe et al., 2007), metabolic syndrome, (Jorde & Grimnes, 2011), and altered lipid levels (Rusconi et al., 2015) and cholesterol (Cutillas-Marco et al., 2013).

Increased serum vitamin D levels and increased HDL-C are associated with decreased risk of CVD (Wang et al., 2008). Vitamin D supplementation in children decreased triglyceride and elevated HDL-C (Hirschler et al., 2014). Ultraviolet (UV) exposure reduces weight gain obesity and metabolic syndrome (Geldenhuys et al., 2014). The investigation of sunlight exposure on lipids is inadequate Hence the aim of this study was to investigate the link between sunlight exposure and dyslipidemia.

Methods and Materials

Ethics Statement

The Study protocol was approved by the Institutional Ethics Committee of the Swamy Vivekananda Medical College Hospital and Research Institute {Ref No: SVMCHRI / IEC/2023/009) for ethical considerations written informed consent, was obtained from all patients and all subjects enrolled in the study.

Study Settings

The study was conducted on outpatients at Swamy Vivekananda Medical College Hospital and Research Institute (SVMCH-RI), TN, India.

Age Group

Subjects are more than 18 years of both sex.

Sample Size Human Subjects

Normal Control group N30, dull sunlight exposure group Dyslipidemia patients (outpatients) N30, bright sunlight exposure group Dyslipidemia patients (outpatients) N30.

Exclusion Criteria

Alcoholic, smoking, chronic diseases.

Inclusion Criteria

Non-alcoholic and non-smoking and no chronic diseases subjects were allowed.

Sunlight Exposure

Normal walking in bright sunlight daily for one hour, in the Morning 8.30-9.30 AM or 4-5 PM daily for one hour for 45 days, and dull sunlight exposure group were: walking daily one hour 5-30 to 6.30 AM or 6.30 PM to &.7.30 PM Dyslipidemia patients N30, (outpatients) for 45= 60 days.

Blood Sample Collection

For ethical considerations written informed consent was obtained from all dyslipidemia patients and all subjects enrolled in the study, based on more than minimal risk ethical guidelines. For the normal subject and dyslipidemia patients before and after sunlight exposure blood samples were collected from the antecubital vein after overnight fasting (Minimum 8 hours) in all the groups and stored immediately in an -80°C fridge.

Methods

Study Parameter

The entire fasting Lipid profile Triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), Very low-density Lipoprotein VLDLC and High-density Lipoprotein cholesterol (HDL–C), and Total cholesterol (TC) were analyzed using an autoanalyzer VITROS 5,1 FS (Ortho-Clinical Diagnostics, NY, USA) whereas in all the study groups 25(OH)D levels were measured using VITROS ECI (Ortho-Clinical Diagnostics, NY, USA).

Result

Association between sunlight exposure and Vitamin D Levels dyslipidemia patients

Subjects were divided into four groups, each group (n30) namely, the Vitamin D Normal control group, the dyslipidemia group, the dyslipidemia dull sunlight exposure group, and the dyslipidemia bright sunlight exposure group The dyslipidemia patient's Vitamin D levels significantly (P< 0.01) reduced compared to the normal control group and dull sunlight exposure group. However, compared with, the bright sunlight exposure group a significant (P< 0.01) increase in Vitamin D levels was observed (Table 1; Fig 1).

Experimental groups	Vitamin D ng/mL
Normal control	29.83333 ± 1.667836
Dyslipidemia (DSL)	15.56667± 1.414789
DSL+ Dull sunlight	16.85± 0.65717
DSL+Bright sunlight	27.21667± 1.806774

Table 1 : Association between sunlight exposure and Vitamin D Levels in dyslipidemia patients

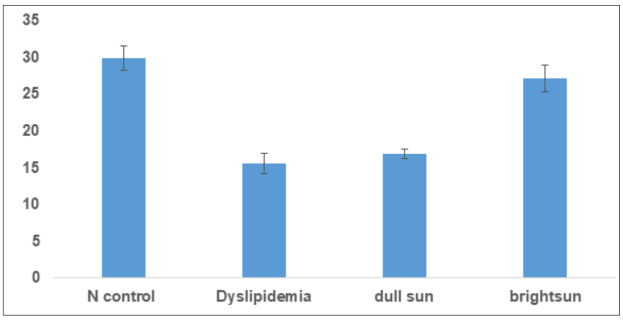

Figure 1 : Effects of sunlight exposure on Vitamin D Level of dyslipidemia patients

Association between sunlight exposure and Dyslipidemia

Sunlight exposure is associated with lipid profile (Patwardhan et al., 2015); the dyslipidemia group significantly (P<0.05) elevated TC, TG, LDL-C, and VLDL-C, and the HDL-C level was significantly (P<0.05) lower when compared to the normal control group.

In the bright sunlight exposure group (n30), the TC, TG, LDL-C, and VLDL-C levels significantly ($P<0.05$) decreased and HDL-C levels significantly ($P<0.05$) increased, compared to dyslipidemia and dull sunlight exposure. It indicates bright sunlight exposure has a significant effect on lipid profile (Table 2, Fig 2).

Experimental groups	TC mg/dl	TG mg/dl	HDL-C mg/dl	LDL-C mg/dl	VLDL-C mg/dl
Normal control	170.4667± 2.203821	67.47± 0.956068	55.70333± 0.864645	89.1± 2.609118	14.86± 0.779831
Dyslipidemia (DSL)	232.3667± 6.955586	250.7333± 5.862189	32.3± 1.302019	156.4667± 0.730019	52.1± 1.280983
DSL+ Dull sunlight	230.5667± 1.870343	245.4333± 2.795976	35.6± 1.078504	149.6± 3.146914	44.76667± 1.557372
DSL+Bright sunlight	178.7± 2.677751	72.86667± 1.531086	54.12± 2.0639	103.5233± 4.154219	23.09333± 0.381516

Table 2: Associated between sunlight Exposure and dyslipidemia patients lipid profile

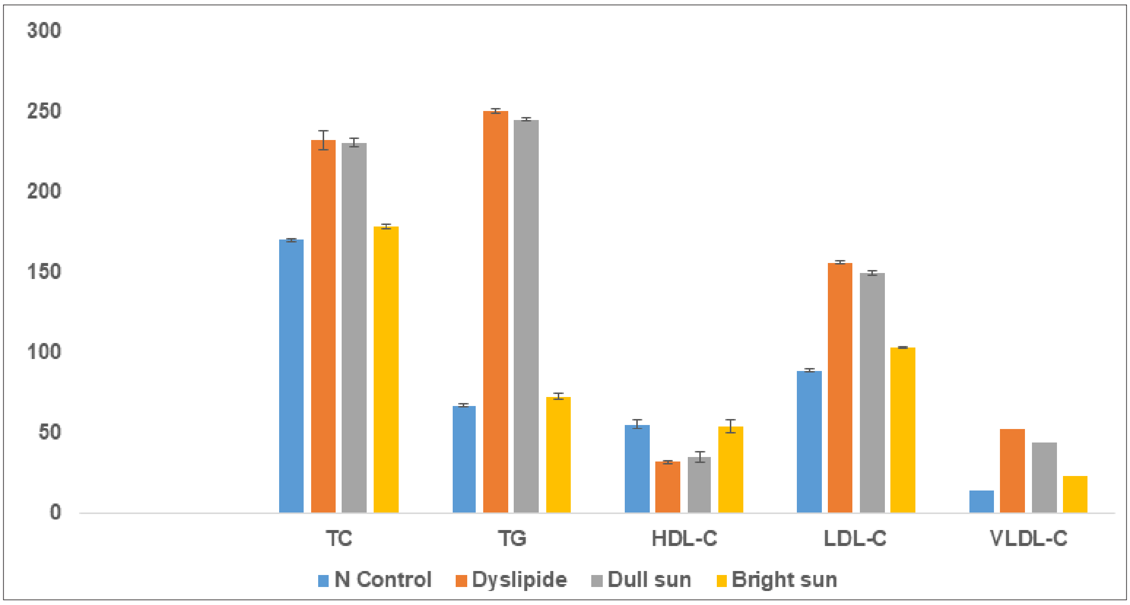

Figure 2 : Effects of sunlight exposure on the lipid profile of dyslipidemia patients

Comparison between oral intake of Vit D and sunlight exposure on dyslipidemia

The oral intakes of Vitamin D dyslipidemia group (n30) TC, TG, and LDL-C levels slightly decreased and HDL-C and Vitamin D slightly increased but did not reach statistical significance. But bright sunlight exposure statistically significantly ($P<0.05$) lowers the TC, TG, and LDL-C levels and increases the HDL-C and Vitamin D, indicating bright sunlight exposure has a better effect on lipid profile compared to oral intake of Vitamin D (Table 3 and 4, Fig 3 and 4).

Experimental groups	Vitamin D ng/mL
Normal control	29.83333 ± 1.667836
Dyslipidemia (DSL)	15.1± 1.21645
DSL+Oral VitD supplement	17.56667± 1.190302
DSL+Bright sunlight	27.61667± 1.456861

Table 3 : Association between sunlight exposure and Vitamin D Levels in dyslipidemia patients and with oral Vit D suppliment

Experimental groups	TC mg/dl	TG mg/dl	HDL-C mg/dl	LDL-C mg/dl	VLDL-C mg/dl
Normal control	170.467± 2.203821	67.47± 0.956088	55.7033± 864645	89.1± 2.609118	14.86± 0.779831
Dyslipidemia (DSL)	232.367± 6.955586	250.733± 5.862189	32.3± 1.302019	156.467± 0.730019	52.1± 1.280983
DSL+Oral VitD supplement	227.1± 7.6221445	221.433± 1122126	39.4667± 3.002492	144.267± 5.977314	45.7± 3.753845
DSL+Bright sunlight	174.033± 4.80719	70.6± 2.258122	52.7887± 2.759091	94.2333± 6.136492	18.9267± 1.56422

Table 4 : Comparison between oral suppliment of Vit D and sunlight exposure on dyslipidemia patients lipid profile

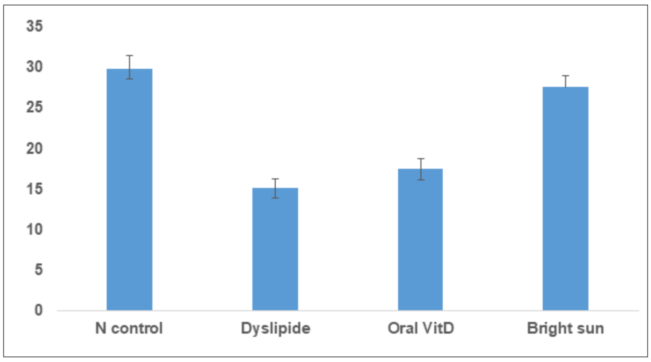

Figure 3 : Comparison between oral suppliment of Vit D and sunlight exposure on dyslipidemia patients Vitamin D level

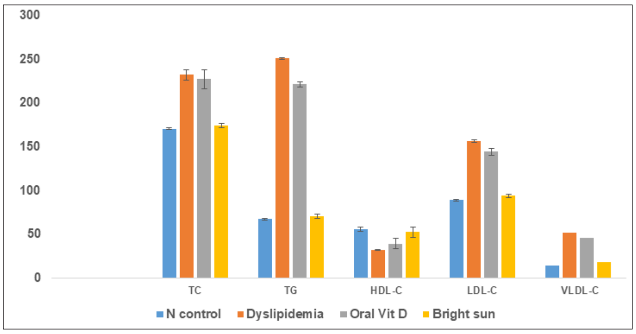

Figure 4 : Comparison between oral suppliment of Vit D and sunlight exposure on dyslipidemia lipid profile

Association between sunlight exposures and obese dyslipidemia patients

In the obese person with dyslipidemia group (n 30) the TC, TG, and LDL-C levels significantly P<0.05 increased and HDL-C and vitamin D levels were decreased compared to normal control. But obese dyslipidemia patients bright sunlight exposure statistically significantly (P<0.05) lowers the TC, TG, and LDL-C levels and increases the HDL-C and Vitamin D levels indicating bright sunlight exposure has a beneficial effect on an obese person's lipid profile (Table 5 and 6, Fig 5 and 6).

Experimental groups	Vitamin D ng/mL
Normal control	29.83333 ± 1.667836
Obese with Dyslipidemia (DSL)	14.86667± 1.567715
Obese DSL+Bright sunlight	27.65± 1.504852

Table 5 : Association between sunlight exposures and Vitamin D Levels in obese dyslipidemia patients

Experimental groups	TC mg/dl	TG mg/dl	HDL-C mg/dl	LDL-C mg/dl	VLDL-C mg/dl
Normal control	171.1333 ± 3.210745	67.47± 956088	55.7033± 864645	89.1± 2.609118	14.66± 1.37307
Obese Dyslipidemia	236.1333± 11.61924	251.8± 9.501758	31.1± 2.024815	154.2± 7.206255	51.63333± 4.171227
Bright sunlight	178.7± 2.677751	72.8667± 1.531066	54.12± 2.0639	101.1± 8.881019	23.09333± 0.381516

Table 6 : Association between sunlight exposures and Obese dyslipidemia patients lipid profile

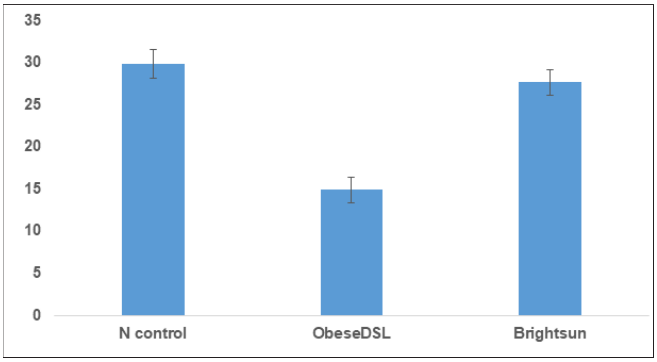

Figure 5 : Association between sunlight exposures and Obese dyslipidemia patients vitamin D level

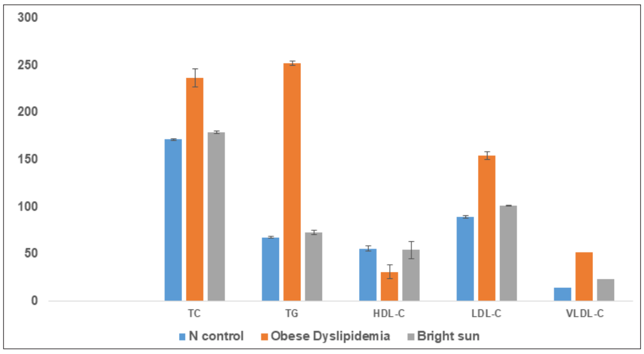

Figure 6 : Association between sunlight exposures and Obese dyslipidemia patients lipid profile

Statistical Analysis

The statistical analysis was completed using SPSS versions 24 and 25 (IBM Corp., Armonk, NY, USA). To estimate the association between the serum vitamin D level and the lipid profile we used Student's t-test and simple linear regression analysis. The Statistical significance ($P < 0.05$).

Discussion

Vitamin D deficiency is a common health problem for humans but is often untreated and unrecognized. Recently, it has been proposed that Sunlight Vitamin D plays an important role in many organ functions including cardiovascular (CVS) health (Stöcklin & Eggersdorfer, 2013). Vitamin D deficiency was associated with highly significant increases in the prevalence of hypertension, CVD (Bouillon, 2019), hyperlipidemia, and diabetes, further Vitamin D is essential for maintaining lipid levels and a normal HDL-C, it prevents the blockage of blood vessels and sedimentation of LDL (Kim & Jeong, 2019). In our study, we observed that there is a relationship between vitamin D synthesis levels and bright and dull sunlight exposure. Our study result showed that bright sunlight exposure has increased vitamin D significantly compared to dull sunlight exposure. A similar result was found in an earlier study by sunlight significantly enhancing serum vitamin D levels (Patwardhan et al., 2017). Further, the present study's result indicated a significant link between sunlight exposure and fasting serum lipids levels in dyslipidemia patients. Our finding showed after bright sunlight exposure, the TGs, LDL-C, VLDL-C, and TCs significantly decreased, and the HDL-C level increased significantly similar results were also observed in the relationship between serum 25-hydroxy-vitamin D [25(OH)D] and lipid profile in the different age groups (Kelishadi et al., 2014). An earlier study has revealed that in both sexes Vitamin D has positively correlated with HDL-C (Kazlauskaite et al., 2010) however, in our study dull sunlight exposure has no significant effect on lipid profile similar result was found in an earlier study (Patwardhan et al., 2015), Oppositely inclined higher sunlight exposure 2 hours per day, serum 25(OH) D level was negatively linked with HDL-C (Patwardhan et al., 2015).

In our study, we found that oral vitamin D supplementation has no significant effect on lipid levels. (Fig: Table :) Similarly, Schwetz V et al. also showed that vitamin D supplementation has no significant effect on lipid levels. Further, Wang et al. (2012) also proposed that vitamin D supplementation did not alter the TC, TG, or HDL-C levels.

Sunlight has both ultraviolet (UV) A and B, in this UVB radiation could trigger Vitamin D synthesis in the skin through a photosynthetic reaction (Kuan et al., 2013). Vitamin D production mainly depends on the number of UVB photons that pierce the skin. However, overexposure to UVB causes sunburn. UVB increases the production of Vitamin D2 from the lipid bilayer and is released into the extracellular fluid. Further, it could alter the membrane permeability to open the pores to permit the entrance and exit of ions including calcium (Holick, 2003; Holick et al., 2007; Tian et al., 1993)

When human skin is exposed to bright sunlight the 7-dehydrocholesterol to pre-vitamin D3 (Holick et al., 1981). It absorbs sunlight UVB and isomerizes into tachysterol and lumisterol (Holick, 1994) these product has an effect on calcium metabolism. Vitamin D regulates calcium metabolism which could increase the absorption of calcium ion from the intestine which reduces intestinal fatty acid absorption (Wang et al, 2016) which in turn reduce the cholesterol level. Further, increasing the calcium ion induces the conversion of cholesterol into bile acids in the liver which reduces the cholesterol level (Vaskonen et al., 2007).

Whenever the Vitamin D level increases the Parathyroid hormone (PTH) level decreases (Morley et al., 2006) which could increase the lipolysis activity and peripheral removal it can reduce the TG level, Vitamin D can reduce TG synthesis, affect lipoprotein metabolism and reduce secretion in the Liver, further, it could enhance the very low-density lipoprotein (VLDL-C) receptor expression.

Various other mechanisms are suggested to explain the role of Vitamin D on lipid metabolism, Vitamin D metabolites inhibited lanosterol 14a demethylase and HMG CoA reductase enzyme activity in various cell lines studied the two enzymes have a major role in cholesterol synthesis (Gupta et al., 1989).

Therefore, an increased vitamin D level via sunlight exposure prompts a decrease in TGs, TCs, and VLDL-C levels and enhances the HDL-C levels (Dziedzic et al., 2016; Asbaghi et al., 2019). Our study showed that bright sunlight exposure could influence the lipid profile it may be via vitamin D therefore, it has significant effects on dyslipidemia and low vitamin D could increase the progression of metabolic diseases like fatty liver (Lee et al., 2017). For this reason, Vitamin D is a marker for lipid profile. Adequate exposure to sunlight is an effective remedy for dyslipidemia.

Conclusion

The results of the present study indicated the relationship between bright sunlight exposure and the lipid profile, and vitamin D of dyslipidemia patients. In the past decades, dyslipidemia has been one of the major risk factors for CVD, and there has been an increasing interest in the prevention of these diseases. As suggested by our study findings, sufficient exposure to bright sunlight enhances the vitamin D level, and within an appropriate range of Vitamin D has an inverse relation with dyslipidemia. Further, it is able to understand the effectiveness of lifestyle modification on dyslipidemia.

Acknowledgments

The authors would like to thank all normal and dyslipidemia patients who participated in the study and the staff of the SVMC Hospital Central Laboratory for their help and support in data collection and for providing the SVMCH-RI research grant- 2023.

Conflicts of Interest

In this study, there are no conflicts of interest.

References

1. Go, A. S., Mozaffarian, D., Roger, V. L., Benjamin, E. J., Berry, J. D., Borden, W. B., Bravata, D. M., Dai, S., Ford, E. S., Fox, C. S., Franco, S., Fullerton, H. J., Gillespie, C., Hailpern, S. M., Heit, J. A., Howard, V. J., Huffman, M. D., Kissela, B. M., Kittner, S. J., …American Heart Association Statistics Committee and Stroke Statistics Subcommittee. (2013). Heart disease and stroke statistics--2013 update: a report from the American Heart Association. *Circulation, 127*(1), e6-e245. DOI: 10.1161/CIR.0b013e31828124ad
2. Yang, Q., Cogswell, M. E., Flanders, W. D., Hong, Y., Zhang, Z., Loustalot, F., Gillespie, C., Merritt, R., Hu, & F. B. (2012). Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA, 307*(12), 1273-83. DOI: 10.1001/jama.2012.339
3. Yusuf, S., Hawken, S., Ounpuu, S., Dans, T., Avezum, A., Lanas, F., McQueen, M., Budaj, A., Pais, P., Varigos, J., Lisheng, L., & INTERHEART Study Investigators. (2004). Effect of potentially modifiable risk factors associated with myocardial infraction in 52 countries (the INTERHEART study): a case-control study. *Lancet, 364*(9438), 937–52. DOI: 10.1016/S0140-6736(04)17018-9
4. Gordon, D. J., Probstfield, J. L., Garrison, R. J., Neaton, J. D., Castelli, W. P., Knoke, J. D., Jacobs, D. R. Jr, Bangdiwala, S., & Tyroler, H. A. (1989). High-density lipoprotein cholesterol and cardiovascular disease. Four prospective American studies. *Circulation, 79*(1), 8–15. DOI: 10.1161/01.cir.79.1.8
5. Sarwar, N., Danesh, J., Eiriksdottir, G., Sigurdsson, G., Wareham, N., Bingham, S., Boekholdt, S. M., Khaw, K. T., & Gudnason, V. (2007).Triglycerides and the risk of coronary heart disease: 10,158 incident cases among 262,525 participants in 29 Western prospective studies. *Circulation, 115*(4), 450–8. DOI: 10.1161/CIRCULATIONAHA.106.637793
6. Bansal, S., Buring, J. E., Rifai, N., Mora, S., Sacks, F. M., & Ridker, P. M. (2007). Fasting compared with nonfasting triglycerides and risk of cardiovascular events in women. *JAMA, 298*(3), 309–16. DOI: 10.1001/jama.298.3.309
7. Wang, Y., Si, S., Liu, J., Wang, Z., Jia, H., Feng, K., Sun, L., & Song, S. J. (2016). The Associations of Serum Lipids with Vitamin D Status. *PLoS One, 11*(10), e0165157. DOI: 10.1371/journal.pone.0165157
8. Subramaniam, V. (2007). Seasonal variation in the incidence of preeclampsia and eclampsia in tropical climatic conditions. *BMC Womens Health*, 7, 18. DOI: 10.1186/1472-6874-7-18
9. Halonen, J. I., Zanobetti, A., Sparrow, D., Vokonas, P. S., & Schwartz, J. (2011). Outdoor temperature is associated with serum HDL and LDL. *Environ Res, 111*(2), 281-7. DOI: 10.1016/j.envres.2010.12.001
10. Yamamoto, H., Zheng, K. C., & Ariizumi, M. (2003). Influence of heat exposure on serum lipid and lipoprotein cholesterol in young male subjects. *Ind Health, 41*(1), 1-7. DOI: 10.2486/indhealth.41.1
11. Neild, P. J., Syndercombe-Court, D., Keatinge, W. R., Donaldson, G. C., Mattock, M., & Caunce, M. (1994). Cold-induced increases in erythrocyte count, plasma cholesterol and plasma fibrinogen of elderly people without a comparable rise in protein C or factor X. *Clin Sci (Lond), 86*(1), 43-8. DOI: 10.1042/cs0860043
12. Wortsman, J., Matsuoka, L. Y., Chen, T. C., Lu, Z., & Holick, M. F. (2000). Decreased bioavailability of vitamin D in obesity. *Am. J. Clin. Nutr, 72*(3), 690–693. DOI: 10.1093/ajcn/72.3.690
13. Dobnig, H., Pilz, S., Scharnagl, H., Renner, W., Seelhorst, U., Wellnitz, B., Kinkeldei, J., Boehm, B. O., Weihrauch, G., & Maerz, W. (2008). Independent association of low serum 25-hydroxyvitamin d and 1, 25-dihydroxyvitamin d levels with all-cause and cardiovascular mortality. *Arch. Intern. Med, 168*(12), 1340–1349. DOI: 10.1001/archinte.168.12.1340
14. Martini, L. A. & Wood, R. J. (2006). Vitamin D status and the metabolic syndrome. *Nutr. Rev, 64*(11), 479–486. DOI: 10.1111/j.1753-4887.2006.tb00180.x
15. Polkowska, A., Głowińska-Olszewska, B., Tobiaszewska, M., & Bossowski, A. (2015). [Risk factors for cardiovascular disease in children with type 1 diabetes in 2000-2010 in Podlasie Province]. *Pediatr Endocrinol Diabetes Metab, 20*(2), 47-54. DOI: 10.18544/PEDM-20.02.0002
16. Giovannucci, E., Liu, Y., Hollis, B. W., & Rimm, E. B. (2008). 25-hydroxyvitamin D and risk of myocardial infarction in men: a prospective study. *Arch Intern Med, 168*(11), 1174-80. DOI: 10.1001/archinte.168.11.1174

17. Wang, T. J., Pencina, M. J., Booth, S. L., Jacques, P. F., Ingelsson, E., Lanier, K., Benjamin, E. J., D'Agostino, R. B., Wolf, M., & Vasan, R. S. (2008). Vitamin D deficiency and risk of cardiovascular disease. *Circulation, 117*(4), 503-11. DOI: 10.1161/CIRCULATIONAHA.107.706127
18. Lappe, J. M., Travers-Gustafson, D., Davies, K. M., Recker, R. R., & Heaney, R. P. (2007). Vitamin D and calcium supplementation reduces cancer risk: results of a randomized trial. *Am J Clin Nutr, 85*(6), 1586-91. DOI: 10.1093/ajcn/85.6.1586
19. Jorde, R. & Grimnes, G. (2011). Vitamin D and metabolic health with special reference to the effect of vitamin D on serum lipids. *Prog Lipid Res, 50*(4), 303–12. DOI: 10.1016/j.plipres.2011.05.001
20. Rusconi, R. E., De Cosmi, V., Gianluca, G., Giavoli, C., & Agostoni, C. (2015). Vitamin D insufficiency in obese children and relation with lipid profile. *Int. J. Food Sci. Nutr, 66*(2), 132–134. DOI: 10.3109/09637486.2014.959902
21. Cutillas-Marco, E., Prosper, A. F., Grant, W. B., & Morales-Suárez-Varela, M. M. (2013). Vitamin D status and hypercholesterolemia in Spanish general population. *Dermatoendocrinol, 5*(3), 358-62. DOI: 10.4161/derm.27497
22. Wang, T., Pencina, M. J., Booth, S. L., Jacques, P. F., Ingelsson, E., Lanier, K., Benjamin, E. J., D'Agostino, R. B., Wolf, M., & Vasan, R. S. (2008). Vitamin D deficiency and risk of cardiovascular disease. *Circulation, 117*(4), 503-11. DOI: 10.1161/CIRCULATIONAHA.107.706127
23. Hirschler, V., Maccallini, G., Tamborenea, M. I., Gonzalez, C., Sanchez, M., Molinari, C., San Antonio de Los Cobres Study Group, Castano, L., Colque, G., Hidalgo, M., & Urzagasti, M. (2014). Improvement in lipid profile after vitamin D supplementation in indigenous Argentine school children. *Cardiovasc Hematol Agents Med Chem, 12*(1), 42-9. DOI: http://dx.doi.org/10.2174/18715257126 66140516102319
24. Geldenhuys, S., Hart, P. H., Endersby, R., Jacoby, P., Feelisch, M., Weller, R. B., Matthews, V., & Gorman, S. (2014). Ultraviolet radiation suppresses obesity and symptoms of metabolic syndrome independently of vitamin D in mice fed a high-fat diet. *Diabetes, 63*(11), 3759-69. DOI: 10.2337/db13-1675
25. Patwardhan, V. G., Khadilkar, A. V., Chiplonkar, S. A., Mughal, Z. M., & Khadilkar, V. V. (2015). Varying relationship between 25 hydroxy vitamin D, high-density lipoprotein cholesterol, and serum 7 dehydrocholesterol reductase with sunlight exposure. *J Clin Lipidol, 9*(5), 652 7. DOI: 10.1016/j.jacl.2015.05.007
26. Stöcklin, E. & Eggersdorfer, M. (2013). Vitamin D, an essential nutrient with versatile functions in nearly all organs. *Int J Vitam Nutr Res, 83*(2), 92-100. DOI: 10.1024/0300-9831/a000151
27. Bouillon, R. (2019). Vitamin D and cardiovascular disorders. *Osteoporos Int, 30*(11), 2167–2181. DOI: 10.1007/s00198-019-05098-0
28. Kim, M. R. & Jeong, S. J. (2019). Relationship between Vitamin D Level and Lipid Profile in Non-Obese Children. *Metabolites, 9*(7), 125. DOI: 10.3390/metabo9070125
29. Patwardhan, V. G., Mughal, Z. M., Padidela, R., Chiplonkar, S. A., Khadilkar, V. V., & Khadilkar, A. V. (2017). Randomized Control Trial Assessing Impact of Increased Sunlight Exposure versus Vitamin D Supplementation on Lipid Profile in Indian Vitamin D Deficient Men. *Indian J Endocrinol Metab, 21*(3), 393-398. DOI: 10.4103/ijem.IJEM_9_17
30. Kelishadi, R., Farajzadegan, Z., & Bahreynian, M. (2014). Association between vitamin D status and lipid profile in children and adolescents: a systematic review and meta-analysis. *Int J Food Sci Nutr, 65*(4), 404–10. DOI: 10.3109/09637486.2014.886186
31. Kazlauskaite, R., Powell, L. H., Mandapakala, C., Cursio, J. F., Avery, E., & Calvin, J. (2010). Vitamin D is associated with atheroprotective high-density lipoprotein profile in postmenopausal women. *J Clin Lipidol, 4*(2), 113–9. DOI: 10.1016/j.jacl.2010.01.006
32. Wang, H., Xia, N., Yang, Y., & Peng, D. Q. (2012). Influence of vitamin D supplementation on plasma lipid profiles: a meta-analysis of randomized controlled trials. *Lipids Health Dis*, 11, 42. DOI: 10.1186/1476-511X-11-42
33. Kuan, V., Martineau, A. R., Griffiths, C. J., Hyppönen, E., & Walton, R. (2013). DHCR7 mutations linked to higher Vitamin D status allowed early human migration to Northern latitudes. *BMC Evol Biol*, 13, 144. DOI: 10.1186/1471-2148-13-144
34. Holick, M. F. (2003). Vitamin D: A millenium perspective. *J Cell Biochem, 88*(2), 296-307. DOI: 10.1002/jcb.10338
35. Holick, M. F., Chen, T. C., Lu, Z., & Sauter, E. (2007). Vitamin D and skin physiology: a D-lightful story. *J Bone Miner Res, 22* (Suppl 2), V28-33. DOI: 10.1359/jbmr.07s211
36. Tian, X. Q., Chen, T. C., Matsuoka, L. Y., Wortsman, J., & Holick, M. F. (1993). Kinetic and thermodynamic studies of the conversion of pre-vitamin D3 to vitamin D3 in human skin. *J Biol Chem, 268*(20), 14888–92. DOI: https://doi.org/10.1016/S0021-9258(18)82416-4
37. Holick, M. F., MacLaughlin, J. A., & Doppelt, S. H. (1981). Regulation of cutaneous previtamin D3 photosynthesis in man: skin pigment is not an essential regulator. *Science, 211*(4482):590-3. DOI: 10.1126/science.6256855
38. Holick, M. F. (1994). McCollum Award Lecture, 1994: vitamin D--new horizons for the 21st century. *Am J Clin Nutr, 60*(4), 619–30. DOI: 10.1093/ajcn/60.4.619
39. Vaskonen, T., Mervaala, E., Sumuvuori, V., Seppänen-Laakso, T., & Karppanen, H. (2007). Effects of calcium and plant sterols on serum lipids in obese Zucker rats on a low-fat diet. *Br. J. Nutr, 87*(3), 239–245. DOI: 10.1079/BJNBJN2001508
40. Morley, R., Carlin, J. B., Pasco, J. A., & Wark, J. D. (2006) Maternal 25-hydroxyvitamin D and parathyroid hormone concentrations and offspring birth size. *J Clin Endocrinol Metab, 91*(3), 906–912. DOI: https://doi.org/10.1210/jc.2005-1479
41. Gupta, A. K., Sexton, R. C., & Rudney, H. (1989). Effect

of Vitamin D3 derivatives on cholesterol synthesis and HMG CoA reductase activity in cultured cells. *J Lipid Res, 30*(3), 379 86.
DOI: https://doi.org/10.1016/S0022-2275(20)38357-7

42. Dziedzic, E. A., Przychodzeń, S., & Dąbrowski, M. (2016). The effects of vitamin D on severity of coronary artery atherosclerosis and lipid profile of cardiac patients. *Arch. Med. Sci. AMS, 12*(6), 1199–1206.
DOI: 10.5114/aoms.2016.60640
43. Asbaghi, O., Kashkooli, S., Choghakhori, R., Hasanvand, A., & Abbasnezhad, A. (2019). Effect of calcium and vitamin D co-supplementation on lipid profile of overweight/obese subjects: A systematic review and meta-analysis of the randomized clinical trials. *Obes. Med*, 15,100124.
DOI: https://doi.org/10.1016/j.obmed.2019.100124
44. Lee, J. H. & Jeong, S. J. (2017). What is the appropriate strategy for diagnosing NAFLD using ultrasonography in obese children?. *World J. Pediatr, 13*(3), 248–254.
DOI: https://doi.org/10.1007/s12519-017-0008-7