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The market of sport supplement in the digital era: A netnographic analysis of perceived risks, side-effects and other safety issues

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ABSTRACT

Background: The market of sport supplements is expanding worldwide. Such phenomenon is often supported by captivating marketing strategies and social media advertising providing unscientifically founded claims, thus raising safety concerns. The aim of our study is to provide a comprehensive analysis of the online market, patterns of use, perceived risks and other safety issues on supplement use as reported in online fitness communities.

Methods: A mixed method approach was employed. An automatized web-based monitoring tool (Brand24®) was used to track the most popular supplements and related discussions according to the number of interactions between users and shares; the number and category of websites; the social media reach; and the most popular hashtags. Results were assessed through a netnographic qualitative analysis of online fitness fora, to identify motivations of intake, self-reported side effects andthe overall safety perception reliability of supplements information online.

Results: A social media reach of over four million individuals, inclusive of 18595 posts, emerged from our search. The most cited supplements were "Whey Protein", "Branched Chain Amino-Acid", "Creatine", "Multivitamin supplements" and "Nitric Oxide boosters". Supplements were mainly taken for muscle gain (23%), increase energy (17%), and weight loss (8%). Although the web narrative on supplementation was overall positive, a wide range of side effects were reported by 19% of fitness fora users. These included acne (9%), water retention (9%), stomach pain (9%), rashes (7%), erectile dysfunctions (7%) and weight gain (5%). Concerns about contamination (47%), counterfeit content (17%) and the presence of hidden ingredients (11%) were also recorded.

Conclusions: In a poorly regulated context, where unsolicited social media posts have replaced the typical advice provided by professionals, efforts should be made to ensure the reliability of the provided information to avoid the insurgence of unwanted adverse effects and safeguard public health.

1. Introduction

In recent years, the supplements/sport foods business has been booming worldwide (Binns et al., 2018), with Europe and North America regions accounting for 30% and 25% of the overall market respectively (Persistence Market Research, 2015). Its estimated value is 163.1 billion USD, with an annual prediction to grow by 6.5% for at least the next five years (Grand View Research, 2021; Research and Markets, 2020). Such a rapid expansion has been facilitated by globalisation and the digitalization of our lives.

Social media platforms are exemplars of this phenomenon. With users thought to account for 42.3% of the world's population by 2022 (Appel et al., 2020), digitized social platforms are considered the most effective and influential technological applications, impacting upon

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daily life in a plurality of ways, from education, to commercial and social life (Alalwan et al., 2017).

The versatility of consumers uses and interactions of said platforms also make them the perfect tool for marketing (Heinze et al., 2020; Miller and Lammas, 2010) and information sharing (Appel et al., 2020). An example of this is the dietary supplements' markets. Supplements and/or sport foods (e.g. gels, bars, drinks, protein powders), ergogenic, herbal and botanical supplements, vitamins, amino acids, weight loss products, among others, are widely advertised on social media platforms (e.g. Facebook, Twitter, Instagram) as "natural" and "safer" alternatives to pharmaceutical products that can be used to improve performance, physical appearance and wellbeing (Mazzoni et al., 2017). Such products are increasingly discussed on Internet fora (e.g. reddit) (Rizvi et al., 2019), which play an important role in facilitating the exchange of information because they are often perceived as virtual "safe" spaces (Zhao and Zhang, 2017). However, the information provided within these platforms is often unverified and unscientifically founded. Instead, there is a heavy reliance on personal anecdotes, leading to misinformed and/or misled users of these platforms, be that due to fraudulence or accident (Dwyer et al., 2018; Torok and Murray, 2008). This is especially significant, if we consider that such products are often promoted by "fitspirational" influencers; a term used to describe individuals with high social media presence who are able to influence the general public via their social media posts about their gym activity and supplement consumption (Carrotte et al., 2017; Kale, 2019).

The concern around supplements being advertised online is aggravated by evidence of their potential (intentional or accidental) adulteration, with undisclosed ingredients, such as New Psychoactive Substances (NPS) or other illicit drugs and compounds not conforming to international regulations on manufacturing, content listing, or labelling (Corazza and Roman-Urrestarazu, 2017; Martínez-Sanz et al., 2017; Tucker et al., 2018; Whitehouse and Lawlis, 2017). This issue has been well documented by a growing number of studies (Carvalho et al., 2012; Cohen et al., 2020, 2018; Dastjerdi et al., 2018; Judkins et al., 2010; Kimergård et al., 2015; Martello et al., 2007; Van Thuyne et al., 2006). Related clinical emergencies and hospitalisations have also been documented (Geyer et al., 2008).

An additional factor that played a major role in the growth of the supplements market is the broadening of the supplement users cohort. Used since ancient times by elite athletes to enhance performance, speed recovery or ease pain (Garthe and Maughan, 2018), supplements have now become widespread among lower level athletes, amateurs, sports people of all ages and the wider general public (CRN, 2018), giving rise to a new concept of "supplementation"(van de Ven et al., 2020).

Although the motivations behind the intake of dietary supplements has typically been linked to a healthy lifestyle or increased sport performance, their use has been more recently associated to aestheticism; the drive to 'look good' and appear "fit" (Mooney et al., 2017). A correlation between supplement use, exercise addiction, appearance anxiety, poor self-esteem and severe obsessive-compulsive behaviours (Body Dysmorphic Disorder (BDM), Muscle Dysmorphia (MD)) has also been observed (Corazza et al., 2019).

Considering the possible health risks associated with unrestricted online availability of supplements, misleading marketing strategies and potential adulteration, our study aimed to gain a better understanding of the online sport supplements' market and to assess (a) the types of products being sold; (b) the quality of information being provided; (c) the motivations associated with their consumptions; (d) the self-reported side effects and (e) perceptions of possible contamination and adulteration.

2. Material and methods

A mixed method approach was adopted, inclusive of both quantitative and qualitative assessments of the material on food supplements available online (Fig. 1). While the quantitative assessment was used to identify the most prevalent (a) fitness supplements sold on the Internet; (b) media platforms (e.g., commercial media, social media, fora, blogs) being used for discussion and (c) fitness fora and websites discussing supplement use for further analysis, the qualitative assessment was used to (d) identify personal insights and motivations behind fitness supplements use and (e) assess any self-reported side effects and/or perceived risks associated with the consumption of supplements and any other safety issues.

2.1. Quantitative assessment

All online platform types from social media sites to generic web domains, online shops, blogs and fora were assessed using the Google search engine. To identify the most popular products sold online, generic keywords such as "most used sport supplement", "most sold sport supplement", and "most popular sport supplement" were entered in the Google search engine. The search was carried out manually for 30 consecutive days (July 15th- August 14th, 2019). All searches were performed in English language.

In order to assess the large amount of data identified from the most popular products and fora of discussion, an automatized online monitoring tool named Brand24® was used. This software provides a real time analysis of the web across multiple channels (e.g., news sites, social media, blogs, fora), allowing for the collection of mentions, discussion volumes and other features in online fora and elsewhere (Ortenzi, 2017). Such tools have also shown to be an effective measure for demographics, sentiments and other variables in social media research, with particular regard to online fora (Ahmed, 2019; Batrinca and Treleaven, 2015). The inclusion criteria for the identification of the most popular products in our search were: (a) number of interactions between users (i.e., communications among audience members); (b) number of shares (i.e., broadcasts of the content on social networks to their connections, groups, or specific individuals); (c) number and category of web sites (e.g., social media, fora, news); (d) social media reach (i.e., the number of users who have come across a particular content on a social platform) and (e) most popular hashtags associated to the keyword (excluding those related to specific brands or distributors). The most popular/relevant fora of discussion were selected according to (a) relevance of research objective: only websites discussing fitness, sport or wellbeing related subjects were considered for analysis; (b) activity of the forum: only thread generated within the past 10 years were included in the study; (c) number of posts every month, (d) frequency of posts: only those with more than seven posts per week were included to ensure that members were actively posting on the forum and (e) all considered fora were publicly accessible. Results were then manually filtered to avoid duplication of results and unrelated mentions.

2.2. Qualitative assessment

The qualitative analysis of the emerged data consisted of a sentiment analysis on the most discussed fitness supplements, alongside a thematic content analysis of the most popular fitness fora previously identified during the quantitative assessment. This was undertaken between September 20th – October 20th, 2019.

2.2.1. Sentiment analysis

The sentiment analysis was implemented using the Brand24® "deep learning" approach. Such an approach enabled the systematic use of natural language processing, text analysis, computational linguistics and biometrics to identify, extract, quantify, and study affective states and subjective information from users across large datasets. The tool automatically recognized the positive, negative and neutral tones of the phrases in-text, providing a polarity index that represents the value of the positive and negative opinion about the given keyword. Results were then manually classified according to their type and source (e.g., supplement commercials, supplement reviews, supplement discussion

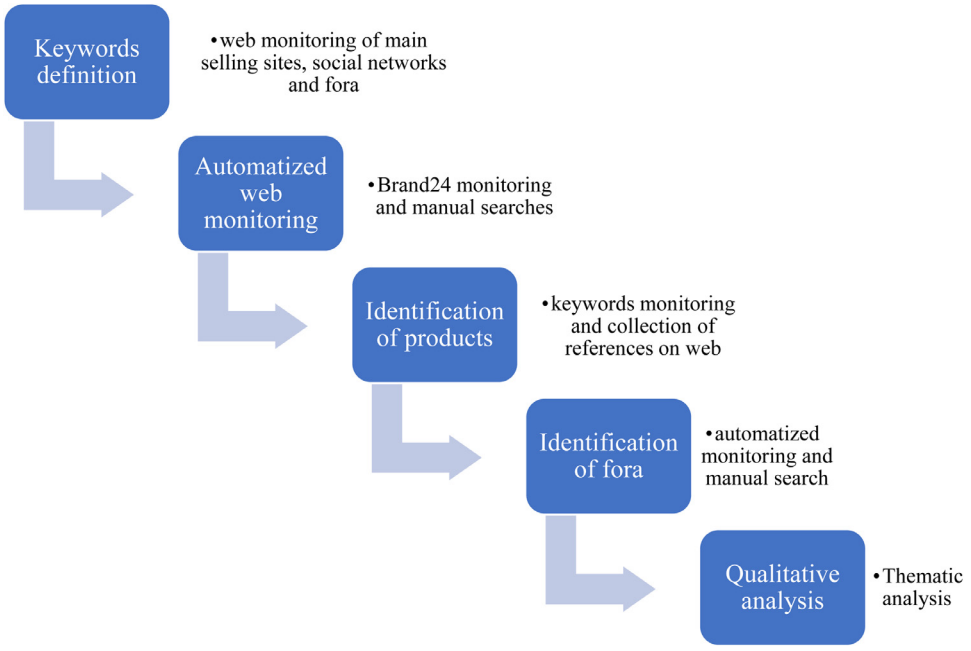

Fig. 1.. Research methodology flow diagram.

threads, supplement news comments, supplement-related possible adverse events report, and other).

2.2.2. Thematic analysis

The most popular fitness fora, were searched for mentions of the supplements identified as most popular. Posts were then subject to manual thematic content analysis, with four key content themes being observed which included motivations for uptake and/or use; experienced side effects; perceptions of contamination; and availability of information. Each discussion thread was then manually classified according to their type and source, which included: supplement adverts; supplement reviews; supplement discussion threads; supplements news commentaries; supplement-related possible adverse events reports; and other.

2.2.3. Ethical Considerations

Due to the inclusion requirement, all fora included within this research were open access and did not require a registration process and/or subscription. All reported materials were considered of public access (Coomber, 2011). The netnographic nature of this research is comparable of that of open-access-media analysis. In this type of analysis, informing fora users of the research potentially disturb the natural posting behaviours on these sites, particularly in the instances of sensitive topics (Kozinets, 2015, 2010; Langer and Beckman, 2005; Tuikka et al., 2017). Hence fora users were not informed of this study. Despite the open access nature of these platforms , in order to minimise any potential damage to the fora users, particularly due to the occasional use of Verbatim quotes throughout this research, every effort was undertaken to ensure the anonymity of all fora posters (Kozinets, 2002; Xun and Reynolds, 2010). No provision of names, profile pictures and/or comments containing distinguishable information was provided in an effort to minimise potential harms (Skågeby, 2009).

3. Ethics Approval

The study was approved by the Human Sciences Ethics Committee at the University of Hertfordshire (HSK/SF/UH/00104) as part of the ongoing monitoring activities undertaken by our team.

Table 1
Automatized online monitoring results of sport supplements related keywords.

Number of mentions	18595
Mentions per category	
Web (including sponsored pages)	7,452 (40,1%)
Blogs	6,568 (35,3%)
Social	3,564 (19,2%)
Forum	723 (3,9%)
News	158 (0,8%)
Other	130 (0,7%)
Number of Interactions	12,978
Number of Shares	1,553
Social Media Reach	4,000,000

Notes. This table (Table 1) shows the total number of mentions on various online resources for generic keywords (e.g. “most used sport supplement”, “most sold sport supplement”) for the selected period. The table also displays the number of interactions and shares between users on the subject, as well as the estimation of the number of users who were exposed to such content (i.e. Social Media Reach).

4. Results

4.1. Quantitative assessment

The automated analysis conducted with Brand24® on the results manually obtained, identified a total of 18,595 references for the generic keywords listed in the method section (e.g. “most used sport supplement” and “most sold sport supplement”). The total Social Media Reach was 4 million, with a total of 12,978 interactions among users and 1,553 shares of contents. The results are shown in Table 1.

The most cited supplements online, as identified by Brand24®, were: Creatine, Branched Chain Amino Acid (BCAA), Whey Protein, Nitric Oxide (NO) boosters and Multivitamin supplements. The number of mentions for each supplement are presented in Table 2, together with the number of interactions between users, the posts shared on social media platform and the individual reached by the content. “Whey protein” was the most discussed fitness supplement on the web, constituting 44,954 interactions and 1,206 shares, with a total of 7.1 million people poten-

Table 2
Mentions for the most discussed fitness products online.

Keyword	Mentions	Mentions per category	Interactions	Shares	Social Media Reach
Creatine	9,375	Social: 2,944 (31,4%) Forum: 394 (4,2%) Blogs: 804 (8,6%) News: 11 (0,1%) Web: 5,222 (55,7%)	6,108	779	3,5 M
Branched Chain Amino Acid / BCAA	8,290	Social: 4,076 (49,3%) Forum: 141 (1,7%) Blogs: 850 (10,2%) News: 28 (0,3%) Web: 3,195 (38,5%)	10,598	638	3,2 M
Whey protein	17,438	Social: 6,616 (37,9%) Forum: 245 (1,5%) Blogs: 1,907 (10,9%) News: 33 (0,2%) Web: 8,637 (49,5%)	44,954	1,206	7,1 M
Nitric Oxide / Nitric Oxide Booster	10,392	Social: 712 (6,8%) Forum: 282 (2,7%) Blogs: 1,100 (10,6%) News: 28 (0,3%) Web: 8,270 (79,6%)	1,502	316	472,000
Multivitamin	9,063	Social: 2,396 (26,4%) Forum: 114 (1,3%) Blogs: 1,815 (20,0%) News: 54 (0,6%) Web: 4,684 (51,7%)	27,912	3,302	2,7 M

Notes. This table (Table 2) displays the number of mentions of the most cited supplements in our quantitative analysis, as well as the number of interactions and shares between users on the subject, and Social Media Reach.

Table 3
Sentiment analysis and related hashtags for sport supplements related keywords.

Mentions	18595
Positive	7771 (86%)
Negative	1261 (14%)
Trending hashtags	#fitness; #workout; #gym; #health; #protein; #weightloss; #mybodyfirst; #nutrition

Notes. This table (Table 3) shows the automated sentiment analysis (i.e. the identification and quantification of affective states and subjective information) for generic keywords (e.g. “most used sport supplement”, “most sold sport supplement”). “Neutral” mentions (i.e. neither positive nor negative mentions) are not considered in the analysis. The table also displays trending hashtags related to the online content.

tially reached by related content. This was followed by Multivitamins (27,912 interactions, 3,302 shares, 2.7 million Social Media Reach) and BCAA (10,598 interactions, 638 shares, 3.2 million Social Media Reach).

Furthermore, the four forum-hosting websites identified as the most popular were: Elitefitness.com; Uk-muscle.co.uk; Gymkaki.com; and Training.fitness.com

4.2. Qualitative assessment

4.2.1. Sentiment analysis

Among the collected mentions, supplements were mainly discussed online in positive terms. The most popular hashtags associated with these products were “#fitness”, “#workout”, “#gym”, “#health” and “#protein” (Table 3). The most positively rated products were “Branched Chain Amino Acids" (87%) and “Whey protein” (81%), and the three most popular hashtags related specifically to these products were “#wellness”, “#healthy”, “#nutrition” and “#lifestyle” (Table 4). Examples of comments identified by the sentiment analysis and classified as “positive” and “negative” are listed within the supplementary material.

Table 4
Sentiment analysis for the most discussed supplements.

Keyword	Positive	Negative	Trending hashtags
Creatine	2,335 (75%)	789 (25%)	#fitness #workout #bodybuilding
BCAA	3,377 (87%)	485 (13%)	#fitness #protein #workout
Whey protein	5,532 (82%)	1255 (18%)	#fitness #supplements #protein
Nitric Oxide (Booster)	580 (69%)	259 (31%)	#health #nutrition #healthylifestyle
Multivitamin	2,750 (81%)	649 (19%)	#health #vegansupplements #wellness

Notes. This table (Table 4) shows the automated sentiment analysis and trending hashtags related to the most cited sport supplements online.

4.2.2. Thematic analysis

The thematic analysis identified a total of 123 relevant discussion threads across the four identified forum-hosting websites. Each of these threads was then manually analysed according to the themes presented in the methods section.

4.2.2.1. Motivations of uptake. A wide range of motivations for uptake and/or use were identified (Table 5) and were subsequently ranked according to the frequency of mention. “Muscle gain” was the most common reason referred to on these platforms for the use of supplements (23%). In this context, muscle gain specifically refers to that undertaken

Table 5
Motivations for supplement use.

Motivation	Percentages
Muscle gain	23%
Energy	17%
Weight loss	8%
Weight gain	7%
Strength	5%
Contribute to effect /reduce side effects	4%
Injury recovery	4%
Fat loss	3%
Muscle maintenance	3%
Blood flow	2%
General health	2%
Overcome plateau	1%
Endurance	1%
Memory loss	1%
Aiding sleep	1%
Cortisol reduction	1%
Stress reduction	1%
Appetite	1%
Hair	1%
Post Cycle Therapy (PCT)	1%
Therapeutic effects	1%
Eyesight	1%
Water retention	1%
Low blood sugar	1%
Stay youthful	1%
Masculinity	1%
Organ health	1%
Cardiovascular health	1%
Bone health	1%
Skin	1%
Confidence	1%
Testosterone production	1%
Physiotherapy after neurological disorder	1%

Notes. This table displays the wide-ranging rationales for the uptake and/or continued use of supplements, as mentioned on the assessed forums as part of the netnographic research component. The percentages reflect the prevalence of mentions of these rationales, with the most cited reasons being 'muscle gain', 'energy' and 'weight loss'.

Table 6
Common side effects reported by supplement users.

Side effect	Percentages
Acne	9%
Water retention	9%
Stomach pain	9%
Rash	7%
Erectile dysfunction	7%
Weight gain (General)	7%
Gas	5%
Diarrhoea	5%
Sweating	2%
Cramps	2%
Kidney stones	2%
Makes unwell (unspecified)	2%
Sleep Deprivation	2%
Worsened OCD symptoms	2%
Burning sensation	2%
Bloating	2%
Increased heartrate	2%
Headache	2%
Urine colour change	2%
Feeling sick	2%
Discoloured urine	2%
Headache	2%
Swelling	2%
High temperature	2%
Dehydration	2%
Constipation	2%

Notes. This table (Table 6) displays the variety of side-effects mentioned by forum posters regarding their use of any sport supplements, on the assessed forums as part of the netnographic research component. Percentages reflect the prevalence of their mentions across the assessed forums, with the most mentioned being 'acne', 'water retention' and 'stomach pain'.

for body image as opposed to strength, which was mentioned only 8 times (5%) across the assessed threads.

The second most commonly self-reported motivation for use was "energy", with 23 (17%) forum discussion threads mentioning the (positive) effects supplements can have on energy levels. This was particularly prevalent in relation to BCAA, Creatine and Multivitamins. The main purpose of increasing energy levels through supplementation was to enhance workouts and training performances, not to boost daily basic energy level.

The following motivations were weight loss and gain respectively, whilst other motivations included: strength; fat loss; injury recovery; muscle maintenance; blood flow; and general health maintenance – a full list along with their prevalence percentages can be viewed in Table 5.

4.2.2.2. Experienced side effects. Overall, 16% of all assessed posts reported side-effects linked to individual posters supplement intake (Table 6). Acne was one of the most commonly mentioned side effects, along with unwanted water retention and stomach pain (9%). Acne was predominantly discussed in relation to the use of Whey Protein, though it did also come up in relation to the use of Multivitamins and Nitric Oxide supplements, too. One forum user discussing this side effect stated: "*Since I started using my new supplements from NO, I have been having some rather bad acne. This is the first time it is happening to me – never thought that just supplements can cause these problems*".

Water retention was mentioned solely in relation to the use of Creatine, while stomach pain was mentioned in posts discussing BCAAs, Whey Protein and Multivitamins and was actively linked by forum contributors as a direct causal effect from the supplements, with one discussion thread specifically titled *"I think my new protein is giving me bad stomach pains"*.

Rashes (7%) and Erectile Inconsistencies (7%) were also reported. The rashes discussed were of various types (body location) and were mentioned only in relation to Whey Protein consumption. Erectile inconsistencies, a term with which here we refer to as either additional erections or difficulties in obtaining an erection, were predominantly discussed in relation to Nitric Oxide and its perceived ability to positively influence this. More side-effects and the regularity of their reference have been reported in Table 6.

4.2.2.3. Perception of contamination issues and other health concerns on supplement use. 10% of all assessed discussion threads contained reference to contamination and products being labelled and sold incorrectly. Whilst 47% of these posts expressed a concern specifically about contaminated products, 18% addressed concerns regarding counterfeit products, 12% mentioned hidden ingredients and 6% referred to the presence of illegal substances in supplements (Table 7). Sometimes, mentions of brands/websites believed to be selling counterfeit products were also made. For instance, one forum user stated: *"most supplements out there have tons of fillers and a pathetic amount of ingredients/dosages. They are worthless. [This brand] actually puts in tons of ingredients in their stuff"*.

4.2.2.4. Sources of information. Results from the thematic analysis (Table 8) showed that, from the 24% of forum threads that specifically mentioned or discussed sources of information for supplementation, a

Table 7
Common concerns regarding products contamination.

Types	Percentages
Contamination	47%
Counterfeit products	18%
Hidden ingredients	12%
Illicit substances	6%
Content scepticism	6%
Quality concern	6%
Misinformation	6%

Notes. This table (Table 7) shows the concerns voiced on the assessed forums, as part of the netnographic research component, regarding the potential health concerns, specifically related to the contamination of supplement products. A total of 47% of the assessed posts mentioned contamination as a concern, with other significant worries being the potential for counterfeit supplement products (18%) and hidden ingredients within said products (12%).

Table 8
Sources of information on supplement use.

Types	Percentages
Academic studies	30%
Online	21%
Fitness influencer	17%
Supplement product manufacturers	13%
Magazines	8%
Blog	2%
Nutritionist	2%
Long-term forum users	2%
Doctor	2%
Amazon	2%
Brand ambassadors	2%

Notes. This table (Table 8) displays the noted, discussed or evidenced ways of information gatheringregarding supplement use, as seen on the assessed forums, as part of the netnographic research component. The most observed information source was academic studies, with 30% of assessed posts mentioning or linking academic research materials. Secondly, the generic 'online' – a specifically vague title in order to encompass the range of online-based resources (21%), and fitness influencers (17%).

wide variety of sources are relied upon. Academic studies were identified as the most popular source of information, with 30% of posts referencing and/or discussing an academic paper/study or providing a hyperlink to a journal article.

The second most cited source (21%) was generically termed "online"; a term which is defined in this context as including supplement-dedicated websites and social media. The third most-referred to source was identified as "fitness influencers" (17%), which is of particular significance due to the lack of regulations on these posts.

Furthermore, "nutritionists" and "doctors" were among the lesser mentioned sources for information, with a mention percentage of only 2%, highlighting the potentially high likelihood of inaccurate information circulation amongst supplments users' communities.

Fora themselves as an information source were excluded from this analysis, as the act of an individual posting on the forum would constitute their procurement of information from this source and it was therefore deemed an unnecessary distinction.

5. Discussion

The implementation of novel netnographic approaches has allowed us to collect and analyse a large amount of real-world data on supplement use, uncovering a wide range of concerns and self-identified side-effects as posted in online communities and social media; platforms which are often considered safe spaces for open discussion. Popular products, such as Creatine, BCAA, Whey Protein, Nitric Oxide boosters and Multivitamin supplements were widely discussed online across a variety of website, fora and social media. Up to seven million people were exposed to comments, advice, and other supplement-related unsolicited content for the period of the monitoring.

The sentiment analysis outcome showed a strong positive attitude towards the supplements identified as the most popular online (Table 4), especially BCAA and Multivitamins. These two were associated with diverse hashtags, including fitness-oriented hashtags (i.e., #fitness, #workout) for BCAA and more health oriented (i.e., #health, #wellness) hashtags for the multivitamin.

Fora and social media posts on supplements were strongly and positively associated to the concepts of sporting success, increased and superior athletic performances, increased success in daily life and general health and wellness. Both the findings of our sentiment and thematic analysis identified common motivations for dietary supplements intake (Table 5); the most common being muscle gain and energy boost. It is important to observe here how "muscle gain" is sought for appearance purposes rather than strength and could be easily associated with the need to reach a "bigger" body shape. This is also true for the other high scoring motivations (e.g., weight loss and weight gain), which makes it difficult to discern the purely sport/performance orientated usage to the one linked to body image ideals and conception. Motivations of intake related to general health and wellbeing were also present but in low percentages (e.g., 2%, 1%).

Side-effects related to supplement consumption were found in 16% of the analysed posts. As highlighted in Table 6, side effects included acne or water retention, followed by stomach pain, rashes and erectile disfunction. Though the water retention was not explicitly stated to be causing harm or pain to anyone, it was regularly cited as an undesirable side effect, predominantly due to the perceived impact on body image. Such results in part confirm those already reported in the literature (Powers et al., 2003; Davies, 2015), which have also being linked to the undisclosed presence of contaminants, such novel psychoactive substances, or adulterants in the purchased products (George, 2003; Tucker et al., 2018; Venhuis et al., 2014). This aspect requires further investigations, especially in terms of the more severe and worrisome side effects, such as compromised kidney dysfunction (Gabardi et al., 2007), liver damage (Gavrić et al., 2018; Krishna et al., 2011) and intestinal bleeding (Zeichner et al., 2014)

From our study, it emerged that the majority of our sample (86%) did not perceive food supplements as risky or dangerous. This finding is supported by the fact that the volume of mentions, interactions and shares on this topic between users was very low (less than 1%). It could be suggested then that supplements and fora users are unaware of both the existence of and types of potential severe risks and side effects associated with food supplements usage.

The same low volume of mentions was found when results were filtered to identify mentions related to supplements' "adulteration and contamination", limited to the 10% of the analysed posts (Table 7). Among these, concerns in terms of potential contamination of the supplements and the presence of hidden ingredients, such as illicit drugs, NPS, etc., were frequently mentioned. Fora users seem to think that the problem of adulteration and contamination is often linked with permissive and unclear legislation (Bailey, 2020; Pereira et al., 2017; Shi and Yan, 2020). This is further evidenced in one forum user's claim when discussing this topic:*"One major issue are the regulations and guidelines for nutritional information on products that are directly correlated with the fitness industry, such as protein, Branched Chain Amino Acids, creatine and fat loss products are too relaxed and often go untested"*, and another commenter was suspicious about the contents, stating that *"Some supplement companies even deliberately spike their products with high doses of Ostarine…"*[sic].

Furthermore, when concerns were raised about a specific product (e.g., side effects), manufactures were found to attribute these to intolerance or other subjective factors specifically related to the individual user rather than the products themselves. It is also possible that negative comments by users may have been concealed/deleted by fora moderators as this information goes against their commercial interests.Scepticism on the provided information and concerns about the quality of the purchased products were also found among the 6% of the examined posts.

However, as suggested by our thematic analysis, the majority of dietary supplement users considered online sources as trustworthy to gather information on supplement use, with only 2% consulting with doctors or nutritionists. Such a result is concerning considering that, currently, there are no legal nor site-specific regulations regarding the provision of information on supplements, meaning the promotion of such products could remain uncertified and potentially inaccurate.

While advice on supplementary intake has typically/hystorically been provided by coaches, medical professionals, and other more trusted and accountable persons (Denham, 2017; Garthe and Maughan, 2018; Garthe and Ramsbottom, 2020; Heikkinen et al., 2011), the results of our work suggest that such advice is increasingly being sought online, often from social media interactions. Many of the identified sources contained fitness supplements' advertisements or reviews (which may be, in some cases, sponsored by a supplement manufacturer). Furthermore, forum users often found scientific information difficult to interpret, thus relying on different interpreters to disseminate the information, such as other forum users and fitness influencers.

Such a shift in advice/information seeking has been further facilitated by captivating and often misleading marketing strategies on social media and other channels (Correia, 2004; Dwyer et al., 2018; Federal Trade Commission, 2001; Starr, 2015; Villafranco and Lustigman, 2007). The lack of control over the latters makes supplements consumption even more risky (Sullivan et al., 2016). As previously argued, the absence of strict regulations and mandatory toxicology tests enables online distributors, as well as physical retailers, to easily sell counterfeit supplements to unaware customers which urge protection (Jackson et al., 2010; Lee et al., 2017).

The scenario depicted by this study is further complicated if one considers the emergence of a new cohort of supplement users aiming at improving their body image (Mooney et al., 2017; Corazza et al., 2019; Dores et al 2021). As we have seen, although the use of supplements has predominantly been associated with elite sports, it is now widespread across all levels , from pro athletes to amateurs and casual gym-goers (CRN, 2018; van de Ven et al., 2020). It was not surprising that most of the web pages retrieved in this study were health blogs reviewing supplements' brands, sports fora discussing specific workout programs and social media threads seeking counselling for beginners. New users often have very low knowledge on sports supplements, and rely on these sources for health advice on how to start their journey with supplementation.Hence they are more prone to be the object of misleading or false claims marketing strategies. These have the potential to fuel supplement intake of a high-risk and uninformed nature, especially among new and inexperienced users.

6. Conclusion

In a context where unsolicited social media posts are being used to promote a wide range of fitness supplements, replacing advice which has been typically provided by coaches, medical and other professionals, efforts should be made to ensure the quality and reliability of this information to the public in order to avoid high-risk supplement use and the emergence of unwanted adverse effects associated with their consumption.

Moreover, while experienced users might be aware of the risks associated with the use of dietary supplements, more vulnerable and inexperienced individuals may be unknowingly exposing themselves to potent and highly toxic drugs, which remain undisclosed on products' labels.

As such, prevention and education activities should be developed to target this new cohort of supplement users, which includes teenagers and young people who often do not receive any medical advice or supervision.

Clinicians should be informed and invited to ask patients about their use of supplements and report suspected adverse events to health agencies, helping to create a toxicity profile and report possible product adulteration. Furthermore, the contamination and/or mislabelling of supplements contents should be more thoroughly assessed in order to better understand the frequency and likelihood of potential dangers linked to the use of food supplements. This could be achieved through collaboration between government/regulatory agencies and academic institutions, as well as with new multidisciplinary approaches designed to provide clear and accessible information across all educational, clinical, research and sporting communities.

Finally, although comprehensive, our results represent only the "tip of an iceberg", which warrants further investigations. The use of big data and artificial intelligence, which are currently specifically developed for and incorporated in general pharmacovigilance and toxicovigilance programs, may facilitate future work in the field and help to anticipate new trends.

7. Study limitations

Our research present findings which need to be interpreted considering the following limitations. First, our analysis is based on anecdotal, self-reported evidenced emerged from contents posted online: the authenticity and reliability of the claims on motivations, side-effects, health concern and related aspects cannot be analytically confirmed since they are solely based on users' experiences. Thus, our findings cannot be generalised. Furthermore, our study only analysed contents in the English language: the implementation of non-English online material would provide a more complete and comprehensive analysis of the topic.

Authors' contributions

Conceptualization, OC, AN, PS,VC;methodology, OC, AN, PS, AT; netnographic collection and analysis, AN, HT, MP; resources: OC; data curation: AN, HT, MP, VC; writing of original draft and preparation writing-review and editing AN, HT, MP, VC; supervision, OC, AT; project coordination: OC; funding acquisition: OC. All authors have read and agreed to the published version of the manuscript.

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Declaration of Competing Interest

Authors declared no conflict of interest

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.etdah.2021.100014.

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